US Army Corps
of Engineers
Construction Engineering
Research Laboratory

USA-CERL

TECHNICAL REPORT N-85/14
September 1985

AD-A162 486

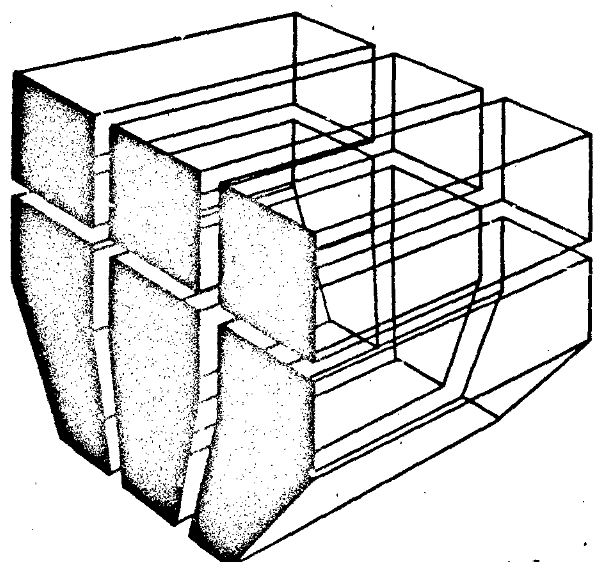
(2)

The Role of Vibration and Rattle in Human Response to Helicopter Noise

by
Paul D. Schomer
Robert D. Neathammer

Our understanding of community reaction to helicopter noise remains incomplete. A technique called "A-weighting" appears to produce realistic data outdoors and at modest noise levels, and the community response in terms of percentage of population highly annoyed can be correlated with respect to the Day/Night Average Sound Level (DNL) descriptor. However, questions remain as to the effect of perceived building vibrations and rattle in human response to helicopter noise. To answer these questions, this study examined the role of vibration and rattle in human response to helicopter noise.

Many volunteer subjects were tested under real noise conditions. The helicopter noise was generated by an Army UH-1H (Huey) helicopter. Subjects were located either in the living room of a new mobile home, outdoors, or in the living room or dining room of an old frame farmhouse near Champaign, IL. The control or comparison sound was generated electronically through loudspeakers at each location using a 500-Hz octave band of white noise. By performing paired comparison tests between the helicopter and control noises, it was possible to establish equivalency between these two stimuli.



Approved for public release; distribution unlimited.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: CERL TR N-85/14
2. GOVT ACCESSION NO.: AD-A162 486
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): THE ROLE OF VIBRATION AND RATTLE IN HUMAN RESPONSE TO HELICOPTER NOISE
5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): Paul D. Schomer, Robert D. Neathammer

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Construction Engr Research Laboratory, P.O. Box 4005, Champaign, IL 61820-1305

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DTFA 01834-10543
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Department of Transportation, FAA Agency, 800 Independence Ave., S.W., Washington, D.C. 20585
12. REPORT DATE: September 1985
13. NUMBER OF PAGES: 158
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
18. SUPPLEMENTARY NOTES: Copies are obtainable from the National Technical Information Service, Springfield, VA 22161
19. KEY WORDS (Continue on reverse side if necessary and identify by block number): helicopters, noise pollution, vibration, rattle

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The understanding of community reaction to helicopter noise remains incomplete. A technique called "A-weighting" appears to produce realistic data outdoors and at modest noise levels, and the community response in terms of percentage of population highly annoyed can be correlated with respect to the Day/Night Average Sound Level (DNL) descriptor. However, questions remain as to the effect of perceived building vibration and rattle on human response to helicopter noise. Does hearing windows, ceiling tiles, or objects in the room rattle or the general perception of building vibration increase the public's adverse response to helicopter noise? To answer these questions,

BLOCK 20 (Cont'd)

this study examined the role of vibration and rattle in human response to helicopter noise.

Many volunteer subjects were tested under real noise conditions. The helicopter noise was generated by an Army UH-1H (Huey) helicopter. Subjects were located either in the living room of a new mobile home, outdoors, or in the living room or dining room of an old frame farmhouse near Champaign, IL. The control or comparison sound was generated electronically through loudspeakers at each location using a 500-Hz octave band of white noise. By performing paired comparison tests between the helicopter and control noises, it was possible to establish equivalency between these two stimuli. The subjects did not know that the role of vibration and rattle was the test's true purpose. USA-CERL researchers and USA-CERL instruments recorded the vibration and rattle levels; the subjects judged only their annoyance to the helicopter noise versus the control noise.

Results showed that the A-frequency-weighting is adequate to assess community response to helicopter noise when no vibration or rattle is induced by the noise and the A-weighted sound exposure level is less than 90 dB. When rattle or vibration is induced by the helicopter noise, however, A-weighting does not assess the community response adequately. Under conditions of "a little" rattle or vibration induced by the helicopter noise, an offset of about 10 dB appears necessary to properly account for community reaction to helicopter noise. When "a lot" of rattle or vibration is induced, the offset necessary to use A-weighting appears to be on the order of 20 dB or more. Moreover, C-weighting offers little or no improvement over A-weighting; the subjective response data still divide based on the levels of vibration and rattle induced by the noise.

In this study, slant distance (distance of closest approach between the helicopter and the location on the ground) offers the best correlation with high levels of rattle. For slant distances in excess of 1000 ft, high levels of rattle usually would not be induced and for slant distances shorter than 500 ft, high levels of rattle would nearly always be produced.

The result suggests a decibel offset of perhaps 5 to 10 dB to assess helicopter noise properly when little vibration or rattle is produced by the noise or when no rattle is produced and the helicopter sound exposure level (SEL) is very high, exceeding about 90 dB. With no rattles and at lower helicopter SELs, there is no offset. No housing or noise-sensitive land uses should be located in zones where high levels of vibration or rattle are induced by helicopter noise; the offset is at least on the order of 20 dB. This high vibration and rattle zone potentially can be delineated by helicopter type and slant distance. For the Army Huey aircraft in level flyover, this zone boundary is at a slant distance somewhere between 500 and 1000 ft. The slant distance zone boundary is expected to differ with type of aircraft and operation.

FOREWORD

This work was performed by the U.S. Army Construction Engineering Research Laboratory (USA-CERL) in cooperation with the U.S. Department of Transportation, Federal Aviation Administration (FAA), under Order No. DTFA 01834-10543 (April 1983).

The following persons are acknowledged for help in developing the test design: Dr. Richard Raspet, USA-CERL; COL Daniel Johnson, U.S. Air Force Aeromedical Research Laboratory; Drs. George Luz and Nelson Lewis, U.S. Army Environmental Hygiene Agency (AEHA); and Dr. Sanford Fidell, Bolt Beranek and Newman, Inc.

Appreciation is expressed to CW3 Richard L. Mathews, CW2 Raymond D. Segorski, and SGT David L. Potter, pilots from Company B, 38th AVN, Michigan Army National Guard, for flying the helicopter and to Countryside Mobile Homes, Inc., Mahomet, IL, for use of the mobile home.

The work was done by USA-CERL's Environmental Division (EN). Dr. R. K. Jain is Chief of USA-CERL-EN.

COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

TABLES

FIGURES

FIGURES (Cont'd)

FIGURES (Cont'd)

FIGURES (Cont'd)

FIGURES (Cont'd)

FIGURES (Cont'd)

THE ROLE OF VIBRATION AND RATTLE IN HUMAN RESPONSE TO HELICOPTER NOISE

1 INTRODUCTION

Background

How communities react to helicopter noise remains only a partially answered question. A technique called "A-weighting" appears to produce realistic data outdoors and at modest noise levels, and the community response in terms of percentage of population highly annoyed can be correlated with respect to the Day/Night Average Sound Level (DNL) descriptor. However, questions remain as to the effect of perceived building vibrations on human response to helicopter noise.[1] Does the sound of windows, ceiling tiles, or objects in the room rattling or the general perception of building vibration increase the public's adverse response to helicopter noise? The Army has received many complaints about helicopter noise that mention vibrating objects or building elements.[2] Attitudinal surveys performed by the U.S. Army Construction Engineering Research Laboratory (USA-CERL) also indicate that rattle and vibration are problems associated with helicopter noise.[3] It appears that the A-weighted DNL may not be sufficiently robust to account for the rattles and vibrations perceived indoors as a result of high levels of helicopter noise.

Purpose

The purpose of this study is to discover if human response to helicopter noise is more negative when the noise induces noticeable vibration and rattles. If so, a second objective is to quantify any offset or adjustment to A-weighting required in helicopter noise assessments when noticeable vibrations or rattles are induced; a third objective is to determine if some other standard metric is better than A-weighting for assessing helicopter noise impact.

Approach

The study was performed using juries of test participants placed in a wood-frame home, a mobile home, and outdoors. A helicopter (Army Huey, type UH-1H) was used to generate the noise stimulus. By varying the slant distance of the helicopter from the test structures, a wide range of single-event flyby sound exposure levels (SELs) were created.

---

[1]T. J. Schultz, "Synthesis of Social Surveys on Noise Annoyance," *Journal of the Acoustical Society of America*, Vol 64, No. 2 (August 1978), p 380.
[2]G. A. Luz, R. Raspet, and P. D. Schomer, "An Analysis of Community Complaints to Noise," *Journal of the Acoustical Society of America*, Vol 73, No. 4 (April 1983), p 166.
[3]P. D. Schomer and R. D. Neathammer, *Community Reaction to Impulsive Noise: A 10-Year Research Summary*, Technical Report N-167/ADA141762 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], November 1983).

Each helicopter flyby was studied as a paired comparison with a shaped burst of white noise in the 500-Hz octave band. The 10-dB-down noise duration approximately equaled the 10-dB-down duration of the flyby. The white noise control was presented either before or after each helicopter flyby and at eight distinct levels, each 4 dB apart from one another. Thus, the eight levels spanned a total range of 28 dB. For each test, the subjects were given the binary choice of stating which was more annoying or bothersome, the helicopter flyby or the control noise. Objective measurements were made of wall and window velocity and acceleration, and the level of vibration/rattle present in each test area was judged subjectively by researchers. These were correlated with the subjects' responses.

Mode of Technology Transfer

The Army will use these data as input to revisions to Army Regulation 200-1, *Environmental Protection and Enhancement*, Chapter 7, "Noise." It is also expected that the Federal Aviation Administration (FAA) will use these data as input for developing recommendations on heliports.

2 STUDY CONCEPTS

Determining the approach to this test has been an evolutionary process among USA-CERL researchers and outside consultants and specialists. Several key technical issues were given great scrutiny and debate before arriving at the test plan used.

In this study, groups of test participants were placed inside the farmhouse, inside a fairly new mobile home, and outdoors. An Army Huey helicopter made a series of flybys over the test area to produce the noise stimulus. To create a wide range of single-event flyby SELs, the helicopter's slant distance from the test structures was varied.

Individual helicopter flybys were studied as paired comparisons with artificially produced shaped bursts of white noise in the 500-Hz octave band. The 10-dB-down noise duration approximately equaled the flybys' 10-dB-down duration. The white noise control was presented either before or after each flyby and at eight distinct levels, each 4 dB apart from one another. The eight levels thus encompassed a total range of 28 dB.

Subjects were not told the real reason for the study--to examine response changes with rattle and vibration. Instead, they were asked to choose which of each pair of noises was more annoying or bothersome and to rate their difficulty in selecting one of the pair. USA-CERL researchers made subjective ratings of vibration/rattle levels, which were correlated with the subjects' response data.

The method used in this study represents a laboratory test of human response to helicopter noise. In a laboratory test, the subjects by definition are not in their homes and not responding to noise as they experience it in their communities. This is in contrast to a community attitudinal survey in which subjects respond to the stimulus as it affects them in their home, work place, or community. Typically, subjects in a community survey respond to the general noise environment and to several specific noise sources such as helicopter operations in their areas. Community response can be categorized in terms such as "percentage of the community which is highly annoyed." The outdoor noise environment is known to a specific degree of accuracy and in a global sense. There is usually no knowledge of the subject's indoor noise environment or life-style. The key to this type of survey study is that subjects respond to their experiences and their environments, but the precise noise stimulus at the subjects' ears remains virtually a mystery. In contrast, in a laboratory study, the stimulus is well quantified, but subjects must respond not to their experience at home, but to what they experience in the laboratory setting. This laboratory test was performed in a real house with real helicopters rather than with tape recordings and loudspeakers. In this way, real helicopter sound and induced rattles and vibrations were the stimuli; a normal laboratory setting could not present these stimuli nearly as realistically.

At least two general approaches have been used to perform laboratory tests on human response to noise. One approach uses magnitude estimation and the other uses paired comparison. In the magnitude estimation study, subjects rate each individual test stimulus. This rating may be numerical, such as rating each aircraft flyby on the basis of 0 through 10; the numerical scale may be anchored with bipolar adjectives such as 0 is "not at all annoying" and 10 is "extremely annoying." As an alternative, the magnitude estimation approach may solely use an adjectival scale, such as the 5-point scale: not at all annoying, a little annoying, moderately annoying, very annoying, or extremely annoying. This type of approach is very useful for developing a large set of data quickly and establishing functional relationships between the variables. However, the adjectival or numerical scales are ordinal and, thus, it is impossible to quantify test results in terms

of decibel adjustments. Moreover, the larger the ordinal scale or number of adjectives, the greater the potential variation from subject to subject and in each subject's individual responses over the course of the test.

A paired comparison test eliminates the ambiguity inherent in the results of magnitude estimation tests. However, the data in a paired comparison test are more difficult to develop and it is a harder test to perform than the other type. In the paired comparison test, study participants rate the test stimuli against one or more control stimuli. Therefore, this approach relies on the experimenter's ability to understand human response to the control stimuli. To achieve this, the experimenter seeks to determine quantitative levels of the study stimuli which are equivalent to the control stimuli in terms of study participants' response; the 50/50 criterion is usually chosen. This means that when 50 percent of the study participants think the control stimulus is less bothersome or annoying and 50 percent think the test stimulus is more bothersome or annoying, the equivalency point is considered to have been reached. Because this is a laboratory test, the test and control stimuli are well quantified and quantitative recommendations can be made based on results of the study.

A modified paired comparison was also considered for this test. Under this modification, each stimulus would have been compared to the most recent previous stimulus. Thus, twice as many judgments would have been made compared to the normal paired comparison method. A test tape was made using helicopter and control signals and a small group of subjects was tested sequentially. The modified method was found to create too great a workload on the subjects, so it was rejected.

Because an objective of this study was to quantify any offset or adjustment required in helicopter noise assessment which results from perceived building vibration and rattles, the normal paired comparison approach was chosen. Up to eight pairs of equivalent levels were established between the helicopter test stimulus and a control stimulus. These are plotted one versus the other, and a departure from a straight line indicates a change in growth of annoyance to the helicopter noise compared with the control noise. With the paired comparison approach, the results are both quantitative and functional; the magnitude estimation approach results would have been functional only, not quantitative.

Once the paired comparison method was chosen, selection of the control signal became the next major issue. Clearly, a wide variety of control signals is available, including one that is a pure tone with a choice of durations (e.g., 1, 10, or 100 sec) and one that is a frequency band of noise with various durations. Since pure tones present standing wave problems in closed spaces, this study used a band of noise. The 500-Hz octave band of white noise was chosen since the A-weighted helicopter spectrum frequently peaks in the 500-Hz octave band. To keep the test and control stimuli similar, it was decided to impart a "haystack" pattern of amplitude modulation to the 500-Hz octave band of white noise (Figure 12 in Chapter 3 is an example of haystack patterns). The control stimulus was chosen such that its 10-dB-down duration most nearly approximated the 10-dB-down duration of the helicopter flyby stimulus.

The physical data incorporated into this test included noise and vibration measurements. In general, two microphones measured the sound exposure in the vicinity of each group of test participants for a total of eight microphones. These microphone signals were recorded on a multichannel recorder and the A-weighted SEL was computed

immediately in the field using USA-CERL noise monitors.[4] Vibration measurements were made adjacent to each of the three groups of indoor test subjects. These measurements used an accelerometer located on a nearby window and a velocity-sensing device located on the nearby exterior wall. The accelerometer output was integrated using the curve recommended by the International Standards Organization (ISO) so both accelerometer and velocity-sensing Geophone output were in terms of velocity.[5] The maximum impulse value of each velocity was recorded in the field using a B&K 2209 sound level meter set to impulse hold. These six channels of velocity information were also recorded on an FM tape recorder. (Recorder size limited the total number of channels recorded to 14--eight microphones and six vibration-sensing devices.)

As an alternative, floor velocity under the subjects could have been sensed rather than wall velocity. However, other studies with blast noise and sonic boom indicate that subjects hear building elements and objects rattle while the actual velocity levels are just at or below the threshold for noticing them.[6] Since the purpose of this test was to see if human response increases when vibrations or rattles are noticeable and, if so, how it increases, the emphasis was on locating the velocity sensors where signals were most representative and easiest to measure. Had the thrust of this test been to study human response to directly perceived vibrations, the velocity sensors would have had to be located on the floor under the subject.

A pretest with an actual UH-1H helicopter at the test house showed that flybys create almost identical velocity levels on the wall and floor. These levels are very low, typically 1 mm/sec or less. Light footsteps create similar or higher levels on the floor but do not register on the wall. So, from a practical measurement standpoint, the wall appeared to be the only reasonable place to locate the Geophone velocity sensors for this experiment.

The primary point to note in the overall approach is that at no time were the terms or ideas "vibration" or "rattle" mentioned to the test subjects. The subjects were instructed to judge each pair according to "Which is more bothersome or annoying? Given the choice, which would you rather not hear again?" For the same noise level, some helicopter sounds created vibration and rattles, others did not. Changes in subject response with the presence of vibrations or rattles with no change in helicopter noise or control level thus would have indicated the need for a "rattle adjustment."

---

[4]A. Averbuch, et al., *True-Integrating Environmental Noise Monitor and Sound-Exposure Level Meter*, Vols I-IV, Technical Report N-41/ADA060958, ADA072002, ADA083320, ADA083321 (USA-CERL, May 1978, June 1979, March 1980).

[5]International Standards Organization (ISO), *Guide for the Evaluation of Human Exposure to Whole-Body Vibration* (ISO Standard No. 2631, 1978).

[6]H. Reicher and F. J. Meister, *The Effects of Vibration on People* [Transl], Report No. F-TS-616-RE (HQ, Air Materiel Command, 1946).

3 DATA COLLECTION

Figure 1 shows the typical data expected from the experiment for a single white noise level. Many of the predicted values were actually seen. The data yield pairs of numbers: the points at which 50 percent of the subjects perceived the helicopter noise to be more annoying than the control white noise level and 50 percent perceived it to be less annoying. These are taken to be the equality points, that is, points at which the helicopter SEL is equivalent to the control SEL in terms of community response.

Two types of data were collected for this experiment--acoustical data and test participant response data. The test site was a country farmhouse and a new mobile home located near the farmhouse. Typically, 10 test participants were located in the farmhouse, five in the mobile home, and five outdoors in the tent. Each group of subjects judged 46 helicopter flybys along with 46 white noise control signals.

The haystack white noise signals were presented at eight different levels, each level being 4 dB different from the adjacent level. Thus, the eight levels spanned a 28-dB range. The control signals had a sloping onset, a rise to maximum, and a faster sloping decay. The indoor SEL of these control signals ranged from about 60 to 88 dB. The house attenuated the outdoor helicopter level by 20 dB. Two loudspeakers were employed in each test room in the house and in the mobile home so as to achieve a substantially uniform sound field within the test participants' area. A set of two microphones monitored both the white noise control levels and the helicopter levels within the test rooms and two outdoor microphones were used to monitor the outdoor sound produced by the helicopter flybys. Accelerometers and/or velocity transducers were used to monitor wall and window motion.

Site Selection

The test site was selected to be in an isolated area to avoid complaints about noise from nearby residents. Several portions of the Champaign County, IL, area were examined and the area directly south of the University of Illinois was chosen as the best region based on three factors:

1. Proximity to the University and Champaign metropolitan area in terms of bringing subjects to the site

2. Proximity to the airport so that the helicopter could be refueled quickly

3. Proximity to the University's south farms which would form a buffer area between helicopter operations and built-up regions of the University.

The criteria established for the test house in terms of location included a rectangular clear zone which extended in the lateral directions from the test house 0.5 mi* in one direction and 1 mi in the other direction and extended along the flight path almost 2 mi in either direction. The goal was to have no other housing in this clear zone and minimal housing in perimeter areas around this clear zone.

---

*A metric conversion chart is on page 53.

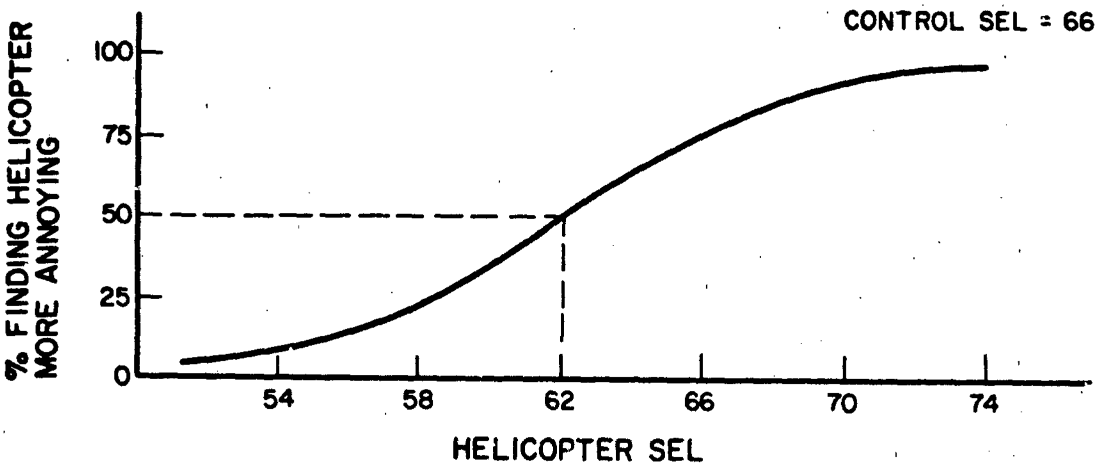


Figure 1. Planned method to determine equivalency between the helicopter and control. In this example, the required offset is +4 dB.

Second, the house had to have proper construction and design for this study. For example, the rooms in which subjects would be placed needed to have windows facing the flight path; the house needed to be of typical wood-frame construction, with no enclosed porches and other similar spaces which could shield the test subjects in an interior location.

Finally, because of the proximity of the University of Illinois' Willard Airport, it was also necessary to choose a test site which was not on an extension of one of the major runways to preclude air-traffic control problems.

The site selected met or exceeded the above criteria. Figure 2 shows the general area, the test site, nearby housing, and the area of helicopter operation. The site is almost directly east of the airport and not in line with any runway centerline extensions. Only two homes (other than the test house) lie within the designated clear zone, one to the north and one to the south of the test house. Few houses adjoin the clear zone. The site is 5 to 10 min (by car) from campus.

To further preclude complaints about noise during the test, a few homes in the clear zone very close to the perimeter were visited and the times of helicopter operation were explained to the residents. Since residents in this area are accustomed to experiments of every type being performed by various units of the University, it was explained that a helicopter study was being performed by the University of Illinois in conjunction with the FAA and the Corps of Engineers (USA-CERL is an adjunct agency to the University of Illinois). USA-CERL personnel distributed the leaflet shown in Figure 3 in the remainder of the areas surrounding the clear zone. If residents were home, the personnel explained that a study was being performed as described in the leaflet; if not, the leaflet was left at the door or in the mailbox. With this precautionary foundation, no noise complaints were registered during the study.

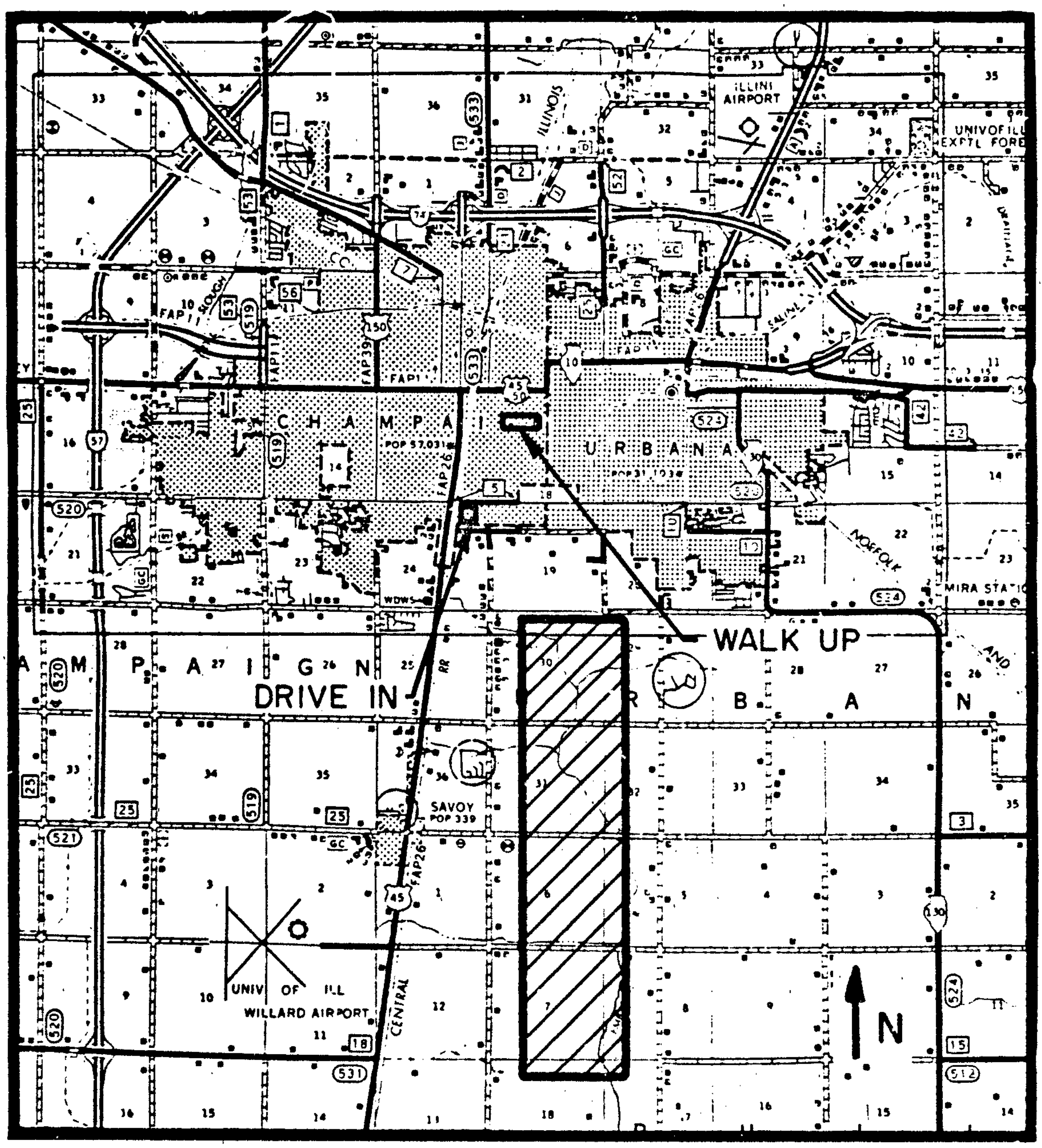


Figure 2. General test site area. Note especially the proximity to the "walk-up" or "drive-in" sites and the airport.

HELICOPTER TEST

Dear Neighbor,

For your information, the US Army Construction Engineering Research Laboratory (which is affiliated with the U of I) and the Federal Aviation Administration are jointly conducting a helicopter test in your vicinity during the period from October 16 to about October 26, 1983. The test will mainly be conducted during mornings (9 am to noon) and afternoons (1:30 to 4:30 pm).

There will be no early morning, late evening or night flying. Only one Michigan National Guard Helicopter will be used for this test. Except for traveling to and from Willard airport, the test will remain in the cross-lined area shown on the map. The altitude of the helicopter will be between 100 feet and 300 feet above ground.

If you have any questions, feel free to call Dr. Paul Schomer at 373-7229.

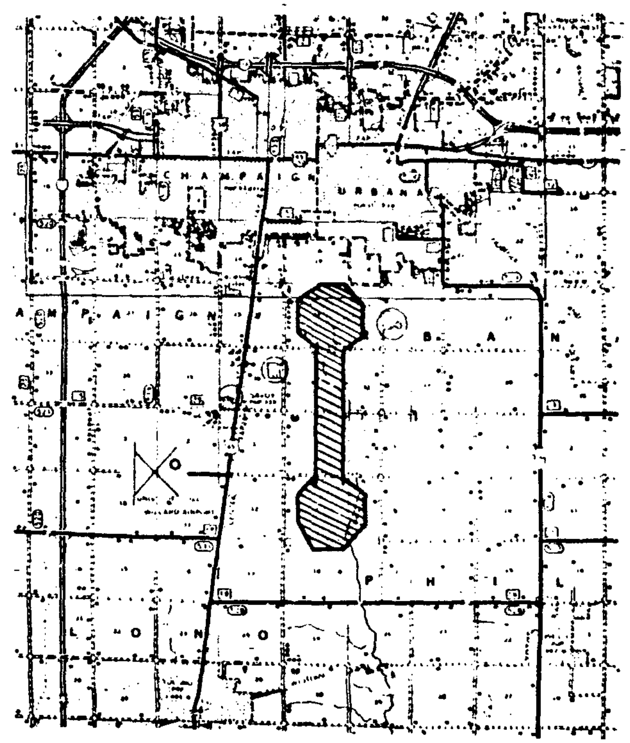


Figure 3. Leaflet describing the test to residents in the test site area.

Site Layout

It was decided to place subjects in (1) the living room of the house, (2) the dining room of the house, (3) the living room of a mobile home which was placed at the test site, and (4) outdoors. Thus, the site had to accommodate ingress and egress of USA-CERL personnel and the test subjects, the mobile home, USA-CERL's test van which housed the acoustical and vibration instrumentation, location of the outdoor test subjects, and instruction and assignment of test participants. Figure 4 is a layout of the test site. In case of rain, a 16- by 20-ft tent was rented and erected on site. The tent provided an area to instruct and divide the test participants into groups and to locate the outdoor test group.

The test house itself was an old, wood-frame farmhouse (Figure 5) currently occupied by an elderly couple. USA-CERL paid for the use of their house during the days for setup and operation of the test. A theodolite with an operator was located about 900 ft east of the test site and was used to verify aircraft height for operations over the site and 400 ft east of the site.

The helicopter flew over the site, 400 ft east, 950 ft east, and 1980 ft east of the site. Large 8- by 8-ft wooden billboards were erected on the mile roads at the site, 1 mi north and 1 mi south of the site at these distances. These were painted orange, white, yellow, and red for the four respective lateral distances (nominally 0, 400, 1000, and 2000 ft) and served as alignment markers for the helicopter.

Subject Selection

Subjects were recruited from the entire Champaign-Urbana area through advertisements in the local and campus newspapers and handbills placed on University billboards. The following text was used in the handbills and the advertisements:

WANTED

> Individuals to assess various sounds for an acoustical study. One entire morning or afternoon during the week of October 17 to 21. Free transportation from on and off campus to and from the test site near Savoy. Test participants will receive $16. Applicants must be literate, able to follow simple instructions, and willing to take a free hearing examination at the U of I Speech and Hearing Clinic. To apply or for more information, call weekdays between 7:30 a.m. and 1:00 p.m. to Judy, Steve, or Race at the Construction Engineering Research Laboratory, 373-7256.

First, candidates were screened for hearing acuity at the University of Illinois Speech and Hearing Clinic. To avoid artificially excluding elderly subjects from the test, it was decided to require that subjects have "good hearing" for their age group. Thus, a greater decibel loss was allowed for more elderly subjects. Table 1 lists hearing acuity requirements.

Candidates who passed the hearing test were scheduled for a test session. Figure 6 is a sample letter with the information sent to each candidate who passed the hearing test. Based on the telephone conversation with the candidate, this letter reiterated the candidate's assignment to a test time and the location of pickup (parking or walk-in).

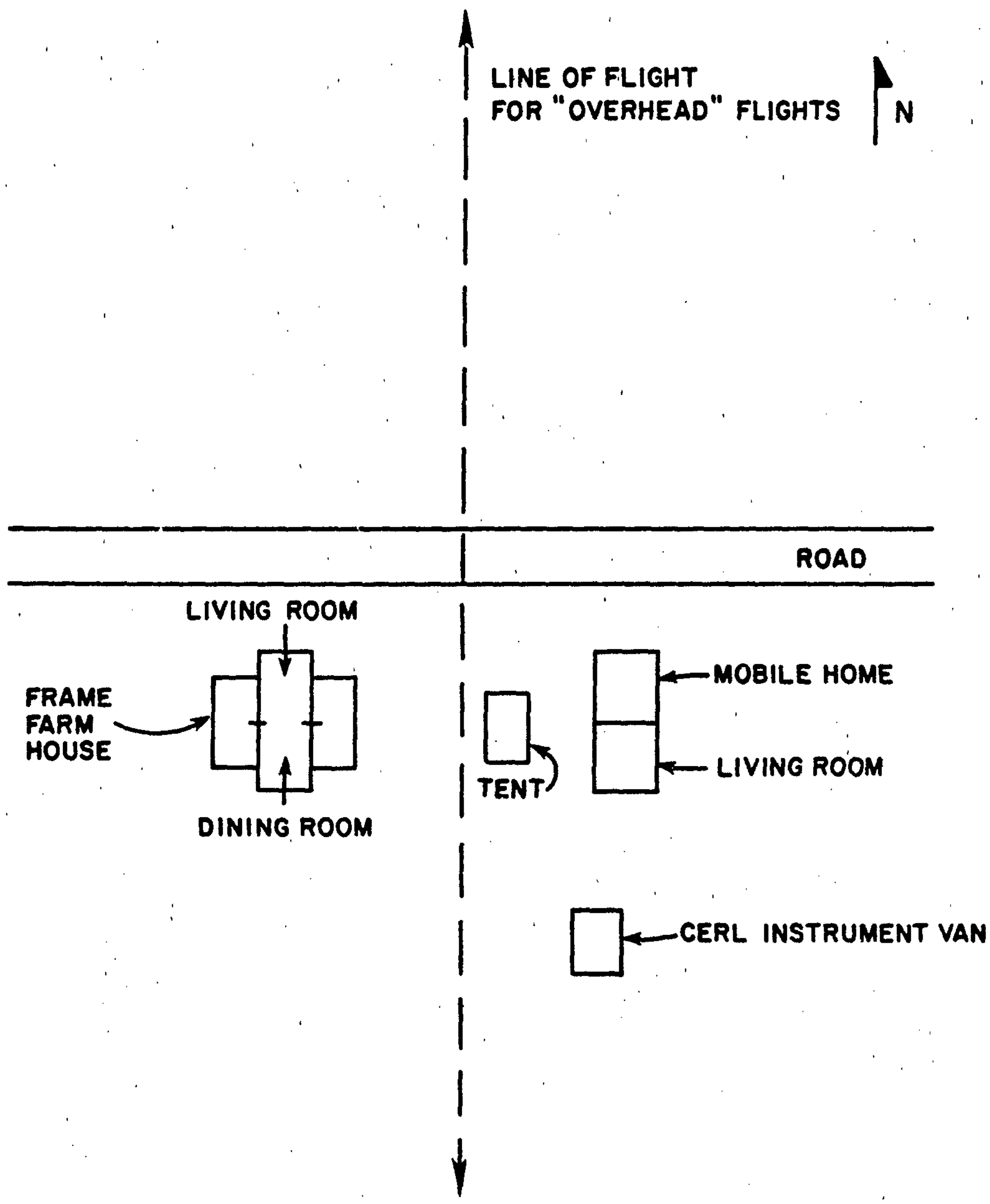


Figure 4. General test site layout.

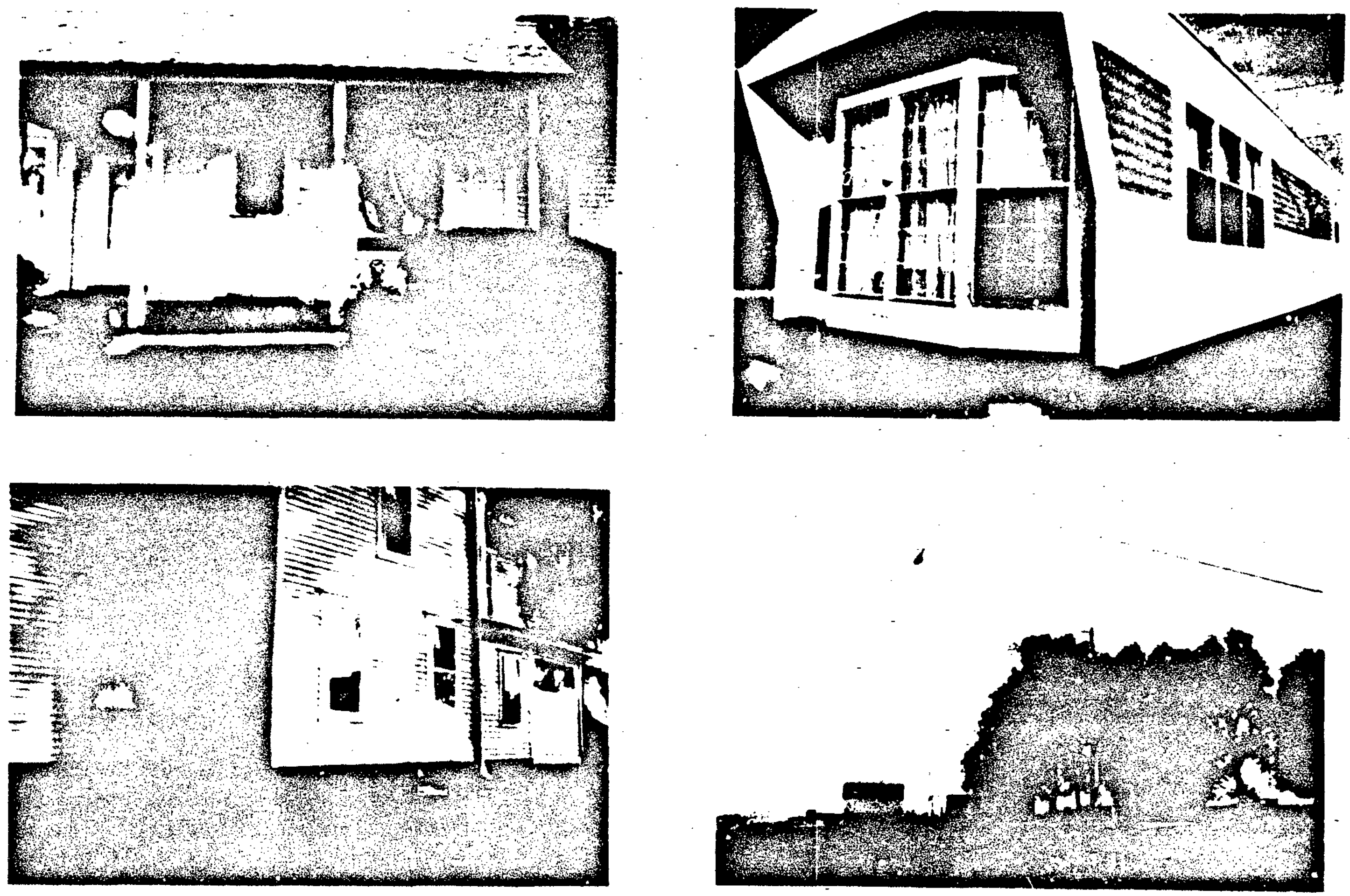


Figure 5. Test site structures: (a) front of house, (b) mobile home, (c) back of house, and (d) back of mobile home and tent.

Table 1

Hearing Acuity Requirements

a. Under age 55*

	Average Loss for the 500-, 1000-, and 2000-Hz Octave Bands (dB)	Loss in the 4000-Hz Octave Band (dB)
1. Each ear	< 25	< 45
2. Both ears	< 30	< 55
3. Better ear	< 25	35

b. Over age 55. (Required for each ear and for both ears together.)

	500-, 1000-, and 2000-Hz Octave Band		
Age	3-Band Average Loss (dB)	Maximum of These 3 Bands (dB)	Loss in the 4000-Hz Octave Band (dB)
56 - 60	< 34	< 40	< 60
61 - 65	< 37	< 45	< 65
66 - 70	< 40	< 50	< 70
71 - 75	< 43	< 55	< 75

*From Army Regulation (AR) 40-501.

INFORMATION FOR TEST PARTICIPANTS

Your hearing has been found satisfactory to be a test subject in the study being conducted by CERL. You are scheduled to participate according to the following circled date.

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Oct. 17	Oct. 18	Oct. 19	Oct. 20	Oct. 21

To be Picked up at ..... West of Assembly Hall
(see Map) ..... Across from Union Book Store

Time 8:25 am 12:45 pm

Test Participants will be driven in groups, in U of I or CERL carryalls, to a site near Savoy and Willard Airport, approximately 4 miles from campus. At the test you will be asked to compare the annoyance of up to 50 helicopter flyovers with the annoyance of a similar number of other sounds. You will have to listen attentively to these sounds for pericds of about an hour between breaks. There will be two of these periods during the test. You may find some of the sounds unpleasantly loud or annoying. None of the sounds will be so loud or long as to impair your hearing in any way.

The only direct benefit to you for participation in this study will be your payment of $16.00. Payment will be made in cash at the end of the testing period.

If for some reason you find that you will be unable to attend please call at 373-7256.

If you have any questions about the nature of today's experiment, please ask them now. If you are satisfied with your understanding of what your participation in this experiment will involve, and are willing to participate, please so indicate by signing the form below.

INFORMED CONSENT FORM

I understand that my participation as a test subject in the experiment being conducted by CERL today will require me to listen to up to 50 helicopter flyovers, and to judge their annoyance relative to an equal number of other sounds. These judgements will be made in the company of other test subjects, seated in groups, for periods of about an hour between breaks. I also understand that some of the sounds I will hear may be unpleasantly loud, but that they will not pose any risk of damage to my hearing.

The only direct benefit to me for my participation in this experiment will be the payment made for my time. I understand that I can freely withdraw from participation in the experiment at any time, and that I will be paid for my participation up to the time I decide to stop. Transportation back to the meeting point will only be available at the end of the experiment, however. I have had the opportunity to discuss the nature of the experiment, and am willing to participate in the study.

DATE:_________________________ SIGNED:_________________________

Figure 6. **Information sent to test participants. Informed consent form is on lower half.**

Including travel, the actual participation in the test took approximately 3-1/2 hr and subjects were paid $13. No subject or candidate received any money until he or she actually participated in the study. The hearing tests were paid for separately by USA-CERL under the terms of a special contract with the Speech and Hearing Clinic.

As indicated, every effort was made to develop a diverse subject body which would include both young and old, male and female, students and nonstudents. However, since subjects were recruited from a campus town, most were students and were young. Table 2 lists the breakdown of subjects by age, sex, and student versus nonstudent.

Site Operation

USA-CERL's acoustics test van was located in the site's southeast corner as indicated in Figure 4. The van contained instrumentation for recording and analyzing the various microphone, accelerometer, and Geophone signals. B&K type 4149 half-inch quartz-coated condenser microphones with desiccators and type 2619 preamplifiers were used inside the house and mobile home. A USA-CERL-developed line-driver was used with each microphone.[7] Two microphones were located in the mobile home living room, two in the test house living room, and two in the test house dining room. Each pair of microphones was located in the area of the room where the test subjects were seated so that the average of the two microphones would form a good approximation of the sound reaching each test subject. Two B&K type 4921 outdoor microphone systems were also used: one in the tent with the outdoor test subjects and the other on a 30-ft pole mounted near the test van. Each microphone signal was analyzed in the test van using the USA-CERL-developed integrating noise monitor and sound exposure level meter and were recorded on an Ampex PR2200 FM tape recorder.[8] An Endevco accelerometer was mounted on a main window facing the line of flight at each indoor location (the mobile home living room, the test house living room, and the test house dining room). A Geophone (velocity transducer) was mounted on the exterior wall of each indoor test site. The three accelerometer and three velocity-transducer signals were recorded directly on the Ampex PR2200 FM recorder. The three accelerometer signals were also integrated using the ISO curve for whole body vibration and measured using a B&K 2209 sound-level meter. The velocity transducers were measured directly (their low frequency cutoff was 4.5 Hz) using a B&K type 2209 sound level meter. Figures 7 and 8 illustrate and Table 3 lists the equipment setup for microphones, accelerometers, and velocity transducers, and Figure 9 shows the ISO frequency-weighting network employed.

Wind speed and wind direction were monitored continually from sensors atop a 25-ft pole attached to the van. Wet and dry bulb temperature readings were made at the beginning, middle, and conclusion of each test session.

A separate area of the test van contained the control signal generation instrumentation. This instrumentation consisted of a white noise generator, an octave-band filter set to the 500-Hz octave band, a Hewlett Packard step attenuator, a programmable attenuator connected to an Apple IIe microcomputer, and amplifiers (Figure 10). The amplifiers ran to loudspeakers located in the four subject test locations. Preprogrammed functions in the Apple IIe varied the control signal 10-dB-down duration and the HP step attenuator was used to vary the control signal amplitude.

---

[7] P. D. Schomer, *Acoustic Patterns for Army Weapons: Supplement 1*, Technical Report N-60/ADA121665 (USA-CERL, September 1982).
[8] A. Averbuch, et al.

Table 2

Breakdown of Test Subjects by Age, Sex, and Student Status

	Age/Sex									
	Under 20		21-30		31-40		Over 40			
Time Period	M	F	M	F	M	F	M	F	Student	Nonstudent
Monday a.m. 18	3	0	2	5	2	6	0	0	7	11
Monday p.m. 17	2	4	4	4	2	0	0	1	14	3
Tuesday a.m. 21 (16 runs only)	5	3	1	9	0	1	1	1	14	7
Tuesday p.m. 20	7	6	3	3	0	0	1	0	19	1
Wednesday a.m. 17	1	4	2	3	1	1	1	4	6	11
Wednesday p.m. 16	3	2	3	2	0	1	1	4	8	8
Thursday a.m. 21	4	3	5	3	2	2	1	1	9	12
Thursday p.m. 15	6	3	3	2	1	0	0	0	14	1
Friday a.m. 23	5	6	0	6	1	2	0	3	16	7
Saturday a.m. 17 (23 runs only)	3	3	3	5	0	1	1	1	14	3
Saturday p.m. 16	3	4	0	3	1	2	0	3	7	9
Total	42	38	26	45	10	16	6	18	128	73

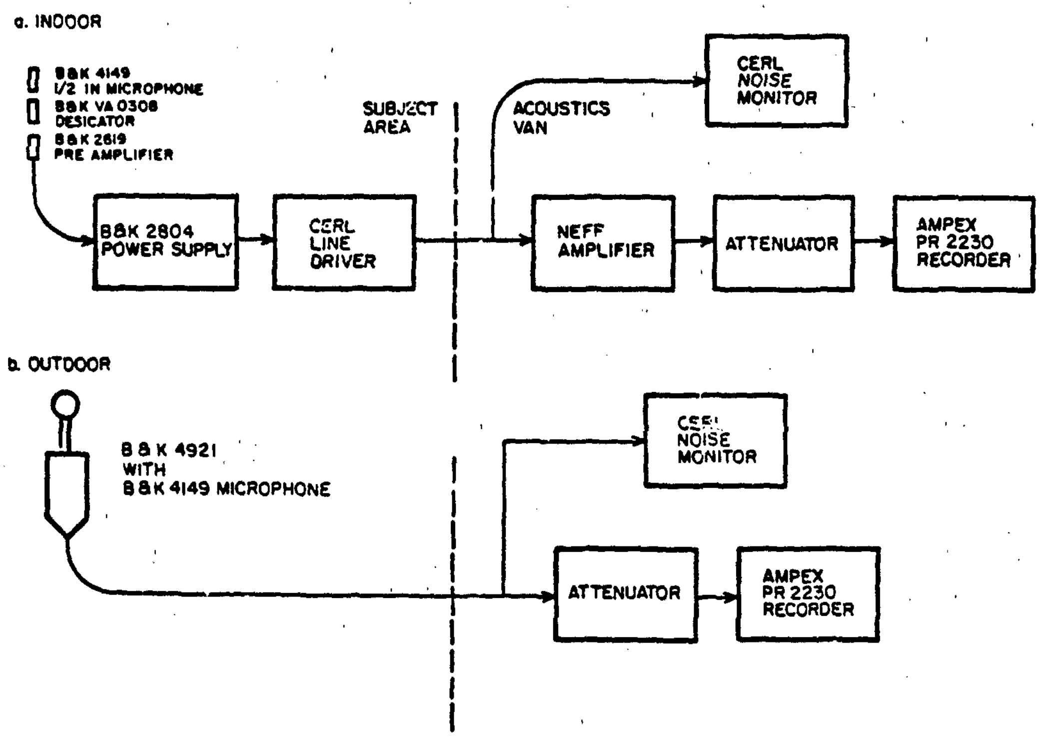


Figure 7. Acoustical data gathering instrumentation.

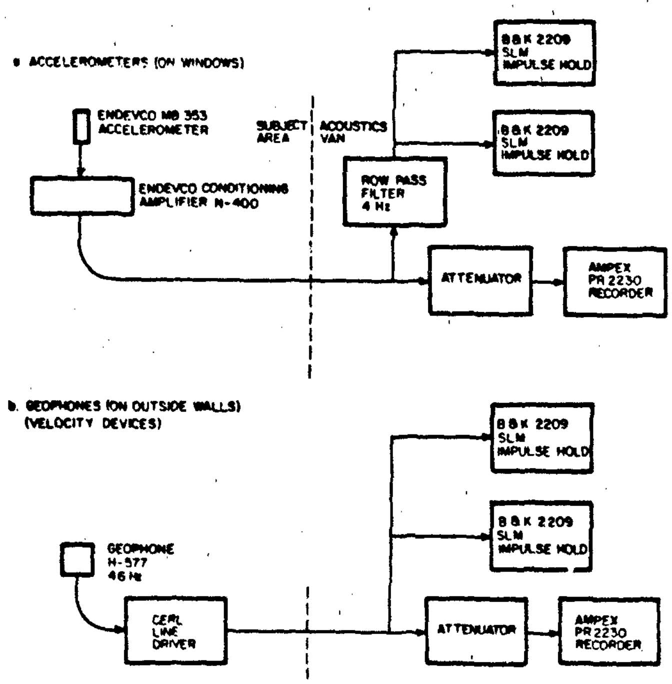


Figure 8. Velocity data gathering instrumentation.

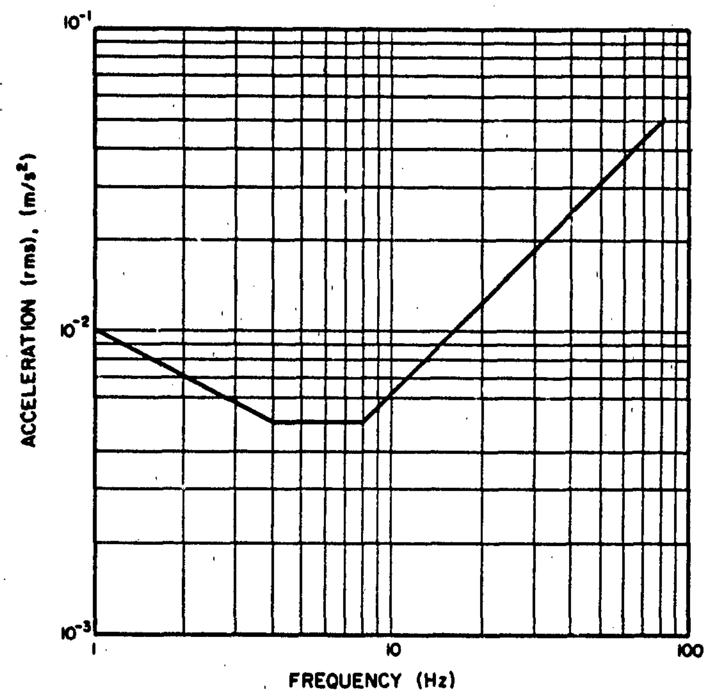


Figure 9. ISO building vibration z-axis base acceptability curve. This represents the foot- (or buttock-) to -head vibration base curve.

Table 3

Acoustic and Velocity Equipment Used in Test Data Gathering

Function	Transducer	Conditioner	Amplifier	Recorder Analyzer
Indoor microphone	B&K 4149 with desiccator	B&K 2619 follower and B&K 2804 power supply	USA-CERL Line driver	AMPEX PR 2200 14 channel FM USA-CERL monitor
Outdoor microphone	B&K 4149 with desiccator	B&K 4921	B&K 4921	As above
Window accelerometer*	Endevco	Endevco summing amplifier*	Endevco summing amplifier*	AMPEX PR 2200 14 channel FM B&K 2209
Wall velocity	Geophone	None	USA-CERL	(impulse hold)

*Measures velocity by using ISO-recommended weighting function after the line driver. The weighting function is essentially an integrator in the frequency range of this experiment.

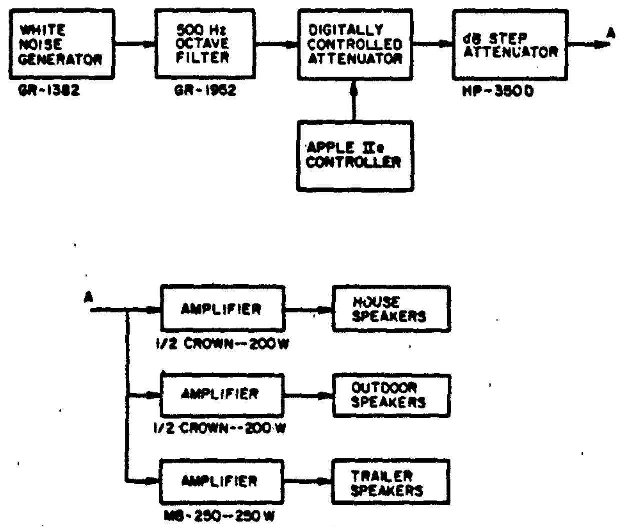


Figure 10. Setup for generating control noise signals.

Subjects were transported by carryall vans from two locations on campus: a walk-up area at one of the main intersections on campus and a drive-in area at a University parking lot where subjects could park their cars free (USA-CERL provided temporary stickers). These two locations are noted on Figure 2 as the "walk up" and "drive in" sites.

Subjects were then asked to sign the consent form shown in the lower half of Figure 6. Subjects arriving onsite were assembled in the tent. Here they received general instructions about the test, written instruction sheets (Figure 11), answer sheets (Appendix A), and pens; they were then divided into the four groups. USA-CERL researchers went with the subjects to their locations and remained there throughout the entire test (one in the mobile home, one between living/dining areas of the house, and one in the tent).

A test period began with three practice comparisons for the subjects. Subjects had to decide which was more bothersome or annoying, the first or second noise in a pair. They also indicated on a 5-point scale how difficult it was to decide which was more annoying; but in every case, subjects were required to decide which of the two sounds was more annoying. The practice comparisons used only the white noise: there was no helicopter for the three practice comparisons. (The Appendix A answer sheets show a helicopter for the third practice, but it was not used.) The first two practice comparisons used widely different SELs so that the answers were obvious and the USA-CERL researcher could be sure that the subjects understood the instructions. The third practice used identical levels for signals A and B so it would be very difficult for the subjects to decide.

After the three practice runs, the regular test commenced, containing 46 paired comparisons split into two groups of 23 separated by a break. During this break, the helicopter refueled and the subjects were paid.

Each paired comparison consisted of four distinct segments: (1) listening to the first sound, (2) listening to the second sound, (3) choosing the more annoying or bothersome sound and marking the answer sheet, and (4) waiting while the helicopter was repositioned. Each paired comparison was scheduled to take 2 min and 45 sec. Half of

INSTRUCTIONS

You are about to take part in a study of the annoyance of helicopter noise. Your job will be to judge which of a pair of noises is more annoying: a helicopter flying nearby or a comparison noise. Because both noises will last for many seconds, you will have to pay careful attention to them for quite some time. You will be seated with a group of other people who will also be judging the annoynace of these pairs of noises. It is your opinion that we are interested in, however, so please do not discuss your judgments with others.

An experimenter will stay with your group for the entire test session to make sure that you understand these instructions and are keeping up with the progress of the study. On each trial, a red light will come on and a beeper will sound when you are supposed to start listening for the first noise of a pair--either the helicopter or the comparison noise. The same light will go out and the beeper will sound when you need no longer pay attention to the first noise. At that same time, a yellow light will come on to tell you to start listening for the second noise of a pair. At the end of the second noise, the yellow light will go out and the beeper will sound again.

At the same time, a green light will come on to tell you to make your judgment. It is very important that you wait until the green light comes on before you decide which of the two noises you have just heard (the helicopter or the comparison noise) is more annoying. Although one or the other of the two noises may seem more annoying while it's in progress, don't make up your mind until the second noise of each pair is over.

Sometimes, it will be easy to decide which of the pair of noises you've just heard is the more annoying. Other times it may not be as easy. You must always make up your mind when the green (third) light comes on, however, even if you think one of the sounds was only slightly more annoying than the other. Make up your mind as soon as possible after the green light comes on and mark your answer. The green light will remain on for about 20 to 30 seconds. Usually it will be followed by a short pause (20 seconds) before the next pair of sounds begins.

The more annoying noise of a pair is the one that you would rather not hear again (if you had to hear one of them again). When you make up your mind whether the helicopter or the comparison noise was the more annoying to you, remember not only how loud the two noises were, but also how long they lasted, and whether any part of either noise was especially bothersome. There are, of course, no "right" or "wrong" answers, but people who listen carefully to both of a pair of noises can often agree which is more annoying. Please give us your honest and considered opinion, and keep an open mind until you've heard all of the second noise of each pair.

Right after you decide which of the pair of noises was more annoying, we'd like you to write down how hard it was for you to make up your mind. If it was very easy to make up your mind which noise was the more annoying, circle the number one ("1") on the answer sheet. Circle the numbers two, three, and four ("2", "3", and "4") for increasingly harder decisions. If it was extremely difficult to make up your mind (that is, if you felt the two noises of the pair were almost equally annoying), circle the number five ("5").

We'll practice your job before the experiment starts. After the experiment starts, however, please do not interrupt other people's concentration by talking. There will be a break after about an hour, when you can get up and walk around for a while. If you have any questions about what you're supposed to do, please ask the experimenter now.

Figure 11. Test participant instructions.

the paired comparisons were performed with the helicopter sound presented first and the control second; the other half were performed with the helicopter presented second and the control first. It was not possible to randomize presentation of helicopter first or second because of the time it would have taken to position the aircraft. Rather, the order was reversed every seven to eight operations. For Monday morning tests, the helicopter was presented first on the first eight paired comparisons, the control signal first on the second eight comparisons, and the helicopter first on the next seven comparisons for a total of 23 paired comparisons during the first half of the morning. For the afternoon session that day, the control signal was presented first on the first eight pairs, the helicopter came first on the second eight pairs, and the control signal came first on the next seven pairs. For further randomization, Monday, Tuesday, and Thursday followed one sequence and Wednesday and Friday followed the alternative sequence.

The command, control, and communication function was centered in the USA-CERL test van where one person operated the control noise generation equipment, a control panel which activated lights and bells in the various test sites and in the van, and communicated with the test aircraft. By operating a switch, this person first simultaneously turned on a red light for 1 min in the van and at all four subject locations. The red light indicated that the subjects should be concentrating on the first sound in the pair. The operator then changed the red light to a yellow light for 1 min, indicating that the subjects should be concentrating on the second sound in the pair. At the end of the second minute, the light was changed to a green light which was on for approximately 15 sec. The green light indicated that subjects should now be making their decision and marking their answer sheet. This sequence of three lights was followed by about 30 sec when no light was on while the helicopter was being repositioned. Each time a light changed, a beep would also sound in each location indicating the light was changing color.

The control noise was generated by setting a prelisted step attenuator level and punching a coded value followed by a return into the Apple computer. The Apple computer then automatically created a 1-min-long control signal with the proper 10-dB down duration. Figure 12 (a and b) shows typical control signals. Basically, the relative level of the control stimulus started at about -70 dB and increased first to -10 dB. Then it increased (usually at a different rate) from -10 dB to 0 dB. As soon as it reached 0 dB, it decayed from 0 dB to -10 dB at one to two times the rate it grew from -10 dB to 0 dB. From the -10 dB level, it decayed to the original -70 dB level at the same rate that it grew from -70 to -10 dB. A set of five 10-dB-down durations were available. These included 5, 10, 20, 30, and 50 sec.

Figure 13 illustrates the helicopter position as a function of time for runs when the helicopter sound was presented first and for runs when the control sound was presented first. This figure is to be interpreted in conjunction with Table 4.

The USA-CERL researchers assigned to the mobile home and house each had a data form on which they recorded their judgments of the vibration and rattles present (Appendix A). They used a 3-point scale which approximately corresponded to the adjectives "none," "a little," or "a lot."

Everyone onsite had matched sets of data forms (Appendix A)--the subjects had their data forms; USA-CERL researchers had a data form; USA-CERL personnel in the van and at the theodolite had various forms for recording aircraft height, weather conditions, signal levels, and attenuator settings; the USA-CERL technician performing the command control and communication function had a set of flip cards (Appendix B)

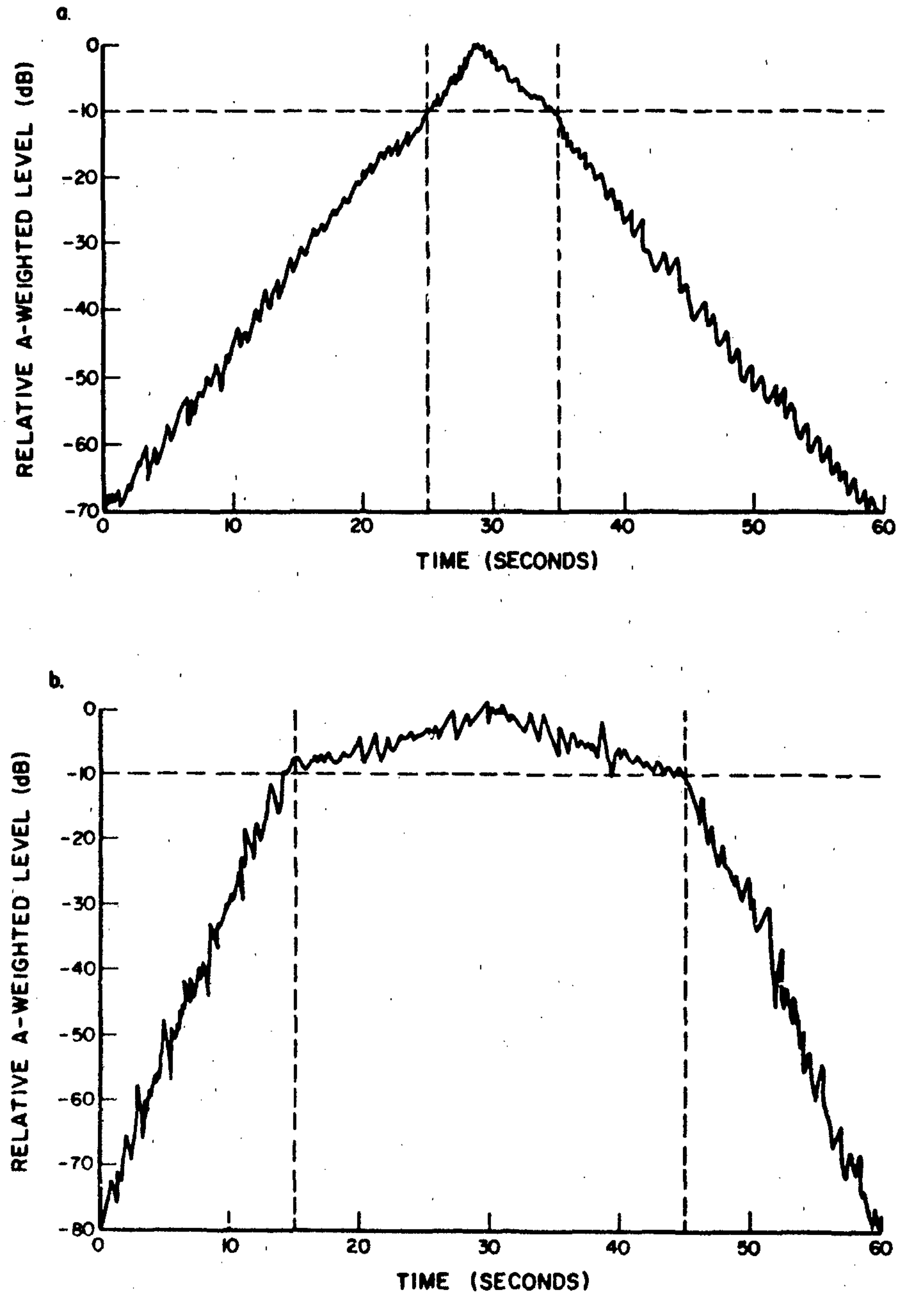


Figure 12. (a) Example of a control signal with a 10-sec, 10-dB-down duration. Note that during the 10-dB-down period (25 to 35 sec), the rise rate is twice the decay rate. (b) Example of a control signal with a 30-sec, 10-dB-down duration. Note that during the 10-dB-down period (15 to 45 sec), the rise rate equals the decay rate.

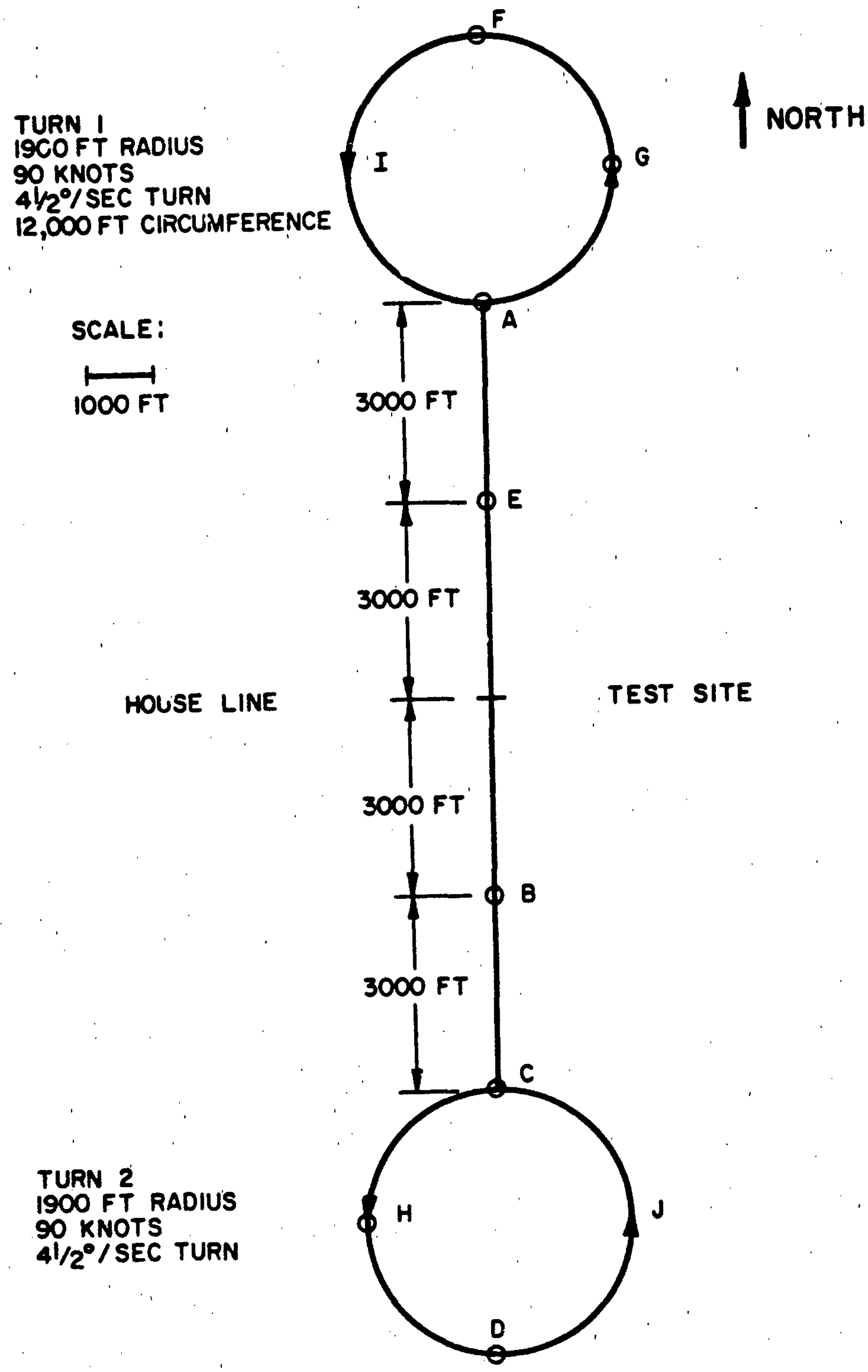


Figure 13. Helicopter flight patterns.

Table 4

Dynamic Flight Patterns

a. Helicopter Signal Presented First

Segment	Distance (ft)	Time (sec)	Subject
AB*	9000	60	Listen to flyby
BCD	9000	60	Listen to control
DC	6000	40	Make judgment
CE	9000	60	Listen to flyby
EAF	9000	60	Listen to control
FA	6000	40	Make judgment

b. Control Signal Presented First

GFA	9000	60	Listen to control
AB	9000	60	Listent to flyby
BCH	6000	40	Make judgment
HDJC	9000	60	Listen to control
CE	9000	60	Listen to flyby
EAG	6000	40	Make judgment

*Segments refer to Figure 13.

indicating the attenuator setting, Apple IIe computer commands, timing, radio calls, and helicopter position; and the helicopter pilot had a set of flip cards (Appendix B) indicating position and radio calls for each flyover.

Data Design

Data collection was randomized by: (1) helicopter and control levels, (2) order of presentation, and (3) direction of flight for a given level. As indicated earlier there were two orders of presentation: one in which the first eight paired comparisons had the helicopter first and one in which the first eight paired comparisons had the flyover first.

Helicopter levels were varied by the natural scatter in flyover levels from one operation to the next and by varying slant distance. The helicopter flew directly overhead at 100 or 200 ft above ground level (AGL) and at sideline distances of 400, 900, and 1950 ft, all at an altitude of 300 ft AGL, to achieve slant distances of 500, 1000, and 2000 ft. So, the total set of slant distances was 100, 200, 500, 1000, and 2000 ft (Figure 14). A variety of control SELs were selected for use with each slant distance to achieve a proper mix of control and aircraft SEL (Table 5). Based on this design, Table 6 lists the actual signal pairs for each of the 46 paired comparisons for each of the two sequences: helicopter first or control signal first. Table 7 summarizes the randomization by slant distance.

As already indicated, the terms "vibration" and "rattle" were never mentioned to the subjects. Therefore, they did not know the purpose of the study was to find and quantify a "rattle adjustment." An article written by one student participant appeared in the campus newspaper describing that subject's reaction to the experiment. The following excerpt helps show that the test's true purpose (i.e., the "rattle factor") was masked successfully:[9]

> The group sat in two banks of carefully placed couches and chairs in front of a set of boxy speakers and a board with four light bulbs sticking out of it. A blond, mustached research assistant explained we would listen first to the helicopter, a stripped-down Huey that looked like it had just flown out of a *MASH* set, and judge its annoyance. When the yellow light came on, we were to circle a number from one to 10 on our forms depending on how much "we would not like to hear it again." Next, we were to rate a grating rumble coming out of the speakers. We did this 49 times.

The article mentions nothing about vibrating/rattling walls and/or windows; instead, it describes the test using only information that had been given in the instructions.

---

[9]J. Morgan, "A Guinea Pig for Defense Sake," *The Daily Illini*.

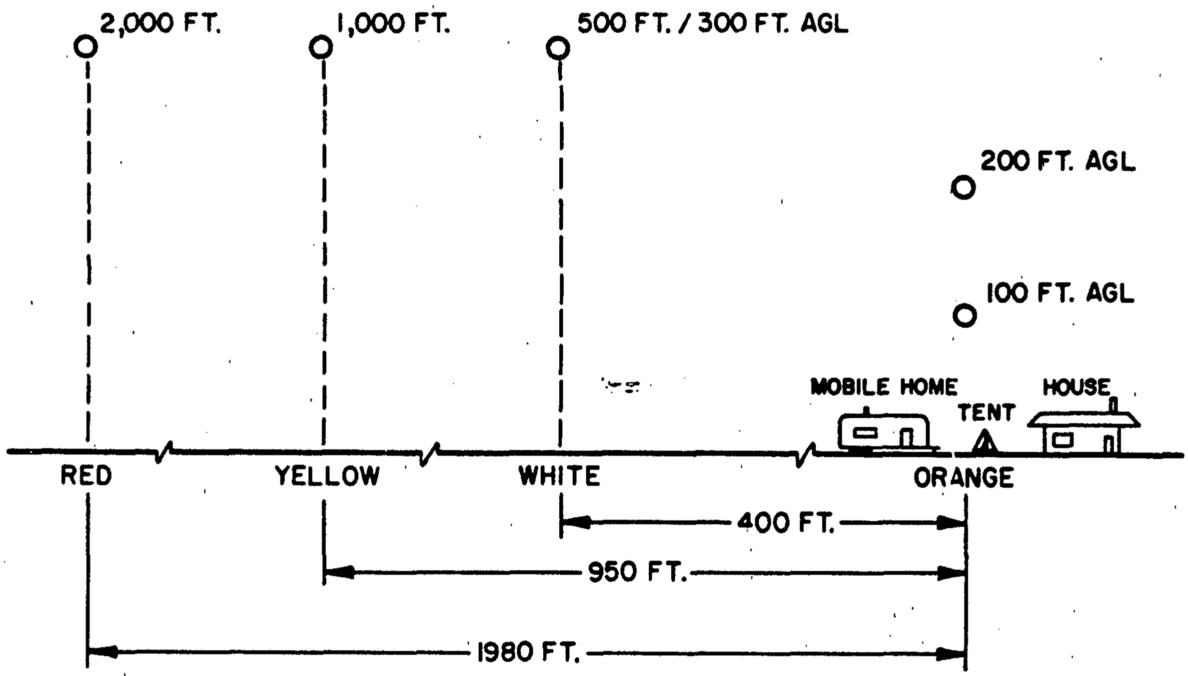


Figure 14. **Point of closest approach (slant distance) for each of the five flight tracks.**

Table 5

Signal Pairs; Control SEL and Corresponding Helicopter Slant Distances

Outdoor Control SEL* (dB) 500 Hz Octave Band of White Noise	Outdoor Helicopter Slant Distances (ft)
108	100
104	100
100	100, 200
96	200, 500
92	200, 500, 1000
88	500, 1000, 2000
84	1000, 2000
80	2000

*Indoor levels were reduced by 20 dB to account for building attenuation.

Table 6

Order of Test Stimuli Presentation

		Pair	Slant Distance (ft)	Heading	Control SEL** Outdoor (dB)
Session A*					
	Group I***	1	200	N	96
		2	2000	S	84
		3	200	N	92
		4	1000	S	88
		5	500	N	92
		6	200	S	92
		7	100	N	104
		8	200	S	100
	Group II***	9	500	N	88
		10	1000	S	92
		11	100	N	108
		12	500	S	92
		13	1000	N	84
		14	500	S	88
		15	500	N	96
		16	200	S	96
	Group III***	17	200	N	100
		18	100	S	104
		19	200	N	92
		20	500	S	96
		21	2000	N	84
		22	2000	S	80
		23	1000	N	88
Session B*					
	Group IV***	24	500	S	88
		25	200	N	96
		26	1000	S	84
		27	1000	N	88
		28	200	S	100
		29	2000	N	88
		30	1000	S	92
		31	500	N	92
	Group V	32	100	S	100
		33	200	N	100
		34	500	S	92
		35	1000	N	92
		36	2000	S	88
		37	500	N	96
		38	200	S	96
		39	100	N	100
	Group VI	40	100	S	108
		41	1000	N	92
		42	500	S	96
		43	500	N	88
		44	1000	S	88
		45	2000	N	80
		46	200	S	92

*Each session took about 1 hr, with a 30-min break between sessions for refueling the helicopter and paying subjects.

**Indoor control SEL were reduced by 20 dB to account for building attentuation of the A-weighted helicopter levels.

***As explained in the text, helicopter and control order of presentation alternated with groups. Monday, Tuesday, and Thursday mornings and Wednesday and Friday afternoons had helicopter first for Group 1. Other times had the reverse.

Table 7

Test Randomization Summary

Slant Distance (ft)	Heading	Helicopter or Control First on a Monday Morning*	Outdoor Control SEL (dB)**
100	N	C	108
	S	C	108
	N	H	104
	S	H	104
	N	H	100
	S	H	100
200	N	H	100
	S	H	100
	N	H	100
	S	C	100
	N	H	96
	S	H	96
	N	C	96
	S	C	96
	N	H	92
	S	H	92
	N	H	92
	S	C	92
500	N	H	96
	S	H	96
	N	C	96
	S	C	96
	N	H	92
	S	H	92
	N	C	92
	S	C	92
	N	C	88
	S	C	88
	N	C	88
	S	C	88
1000	N	H	92
	S	C	92
	N	C	92
	S	C	92
	N	H	88
	S	H	88
	N	C	88
	S	C	88
	N	C	84
	S	C	84
2000	N	C	88
	S	H	88
	N	H	84
	S	H	84
	N	C	80
	S	H	80

*As explained in the text and Table 5, helicopter and control order of presentation alternated with groups.
*Indoor control SEL were reduced by 20 dB to account for building attenuation of the A-weighted helicopter levels.

4 DATA REDUCTION AND RESULTS

The various sets of data accumulated during this study included subjects' responses, both A-weighted and C-weighted measured SELs near the subjects, measured maximum impulse ISO vibration levels of the windows and walls, and USA-CERL researcher judgments of vibrations and rattles at the indoor test locations on the 3-point scale.

Basic Data Division

The control signals were set up to yield eight distinct SEL levels at each location, each level separated from the next by 4 dB. However, use of white noise with its inherent statistical variation in a narrow band (500-Hz octave band in this case) was enough to cause considerable variation in measured SEL from one run to the next. Therefore, it was decided to split the data based on control signal level into 4-dB-wide bins spread over about a 28-dB-wide range. Table 8 illustrates the range of data developed at the four subject locations. Once the data were split into bins, it was possible to plot percentage of respondents finding the helicopter more annoying for given helicopter and control SELs. Figure 15 shows a typical curve. Appendix C contains indoor results. In this appendix, A-weighted SEL is used throughout. On each curve, the data are split based on the USA-CERL researchers' judgments about the three vibration levels: none, a little, or a lot.

Figures C1 through C7 in Appendix C show that, in the mobile home, the data were homogeneous and did not divide on the basis of vibrations or rattles. This is also evident in Figure 15 where the dashed regression line is fit to the total data set. This result was not surprising since the mobile home was new and had 6 in. of wall insulation, windows that did not rattle, and rather tight construction. There was, however, an overall low frequency "resonance" when the helicopter flew over. Outdoors in the tent, no effort was made to distinguish vibration levels, although the tent roof sometimes flapped from the helicopter overhead.

In the house living and dining rooms, the data clearly divided based on the USA-CERL researchers' subjective evaluation of the vibration and rattles. Figure 16 is typical of these data but is for the living room and dining room combined as described below. Various attempts were made to find objective measures of the accelerometer and Geophone readings which would cause the data to divide as cleanly or more cleanly than did the USA-CERL researchers' subjective evaluations in the house, but nothing except the most artificial of measures could be found. The only indicator which worked at all well was the level of acceleration of the living room window, which turned out to be the primary source of rattle in the living room. In the dining room, the window which rattled the most faced west, but the accelerometer was mounted on the south-facing window which was in the helicopter's line-of-flight. Signals produced by the vibration transducers mounted on the walls were found to serve little purpose.

On the basis of these results, the following initial conclusions were developed: (1) The mobile home data did not divide based on either subjective or objective measures of vibration and thus were aggregated solely on the basis of A-weighted noise levels. These data are illustrated in Appendix D along with the tent data which were initially aggregated solely on the basis of noise level. (2) The data in the living room and dining room within sets were quite similar and aggregated together into the liv-din combination (Appendix D); these data did divide based on the USA-CERL researchers' subjective evaluation of the vibrations and rattles present.

Table 8

Division of Data Into 4-dB-Wide Bins*

Tent	Indoor Locations
80 - 84	60 - 64
84 - 88	64 - 68
88 - 92	68 - 72
92 - 96	72 - 76
96 - 100	76 - 80
100 - 104	80 - 84
104 - 108	84 - 88

*There is a nominal 20-dB shift from outdoors (tent) to indoors to account for building attenuation of A-weighted helicopter SELs.

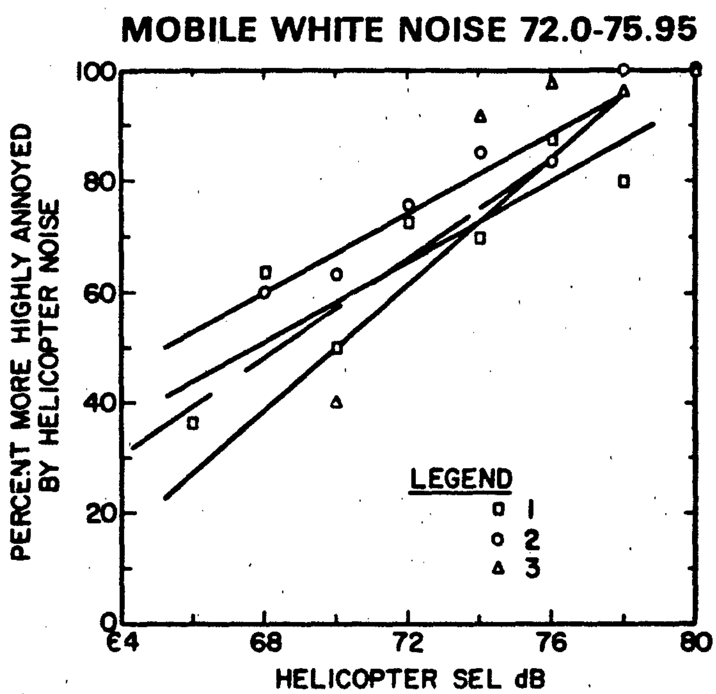


Figure 15. Typical data from the mobile home. The data are split based on the USA-CERL researchers' subjective evaluation of the vibration and rattle present. The ratings were on a 3-point scale as the legend shows, with 1 = none, 2 = a little, and 3 = a lot.

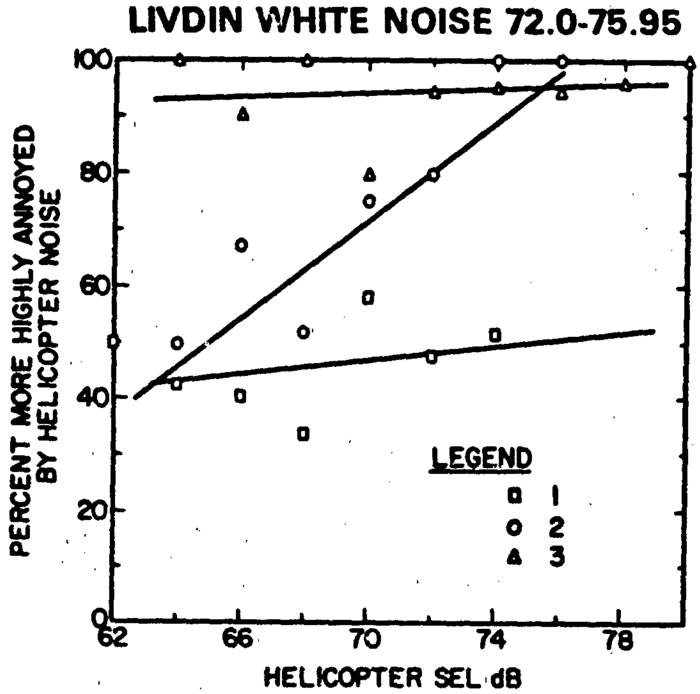


Figure 16. **Typical data from the house living or dining room. The data are split and clearly divided based on the USA-CERL researchers' subjective evaluation of the vibration and rattle present. The ratings were on a 3-point scale as the legend shows, with 1 = none, 2 = a little, and 3 = a lot.**

As shown in Appendix A and the instructions to the subjects (Figure 11), the subjects could not use "undecided" as an answer; they had to choose between the two sounds. They did, however, indicate the difficulty in making a choice on a 5-point numerical scale. To eliminate questionable data, a simple criterion was developed to flag data for which there were only a few subjects and they had a hard time deciding since these data points would have the greatest probability of error. This procedure is evident in Appendices C and D; data points are circled when the number of subjects choosing those values was less than 1.5 times their average difficulty in deciding.

Regression lines (solid) were fit to all the data sets in Appendices C and D (data sets having three or more points only). If significant, a new regression line (dashed) was approximately fit to data sets with one or more questionable (circled) data points, provided three or more uncircled data points remained.

A-Weighted Data Results

Equivalency in this study is established between a helicopter SEL and a control SEL for equal annoyance when 50 percent of the subjects find the helicopter noise more annoying and 50 percent find the control sound more annoying. In each curve in Appendix D, the regression line has been used to estimate the 50/50 equivalency point. Frequently, for the high vibration level in the liv-din area, the data are offscale and no 50/50 point

can be estimated. It seems clear, however, that this point is at least 20 dB offset; that is, the control noise would have to be 20 decibels louder than the measured helicopter SEL for there to be an equivalent annoyance when high levels of vibration and rattle are present. Table 9 lists the helicopter SEL found equivalent to the control SEL for the various subject sites and vibration groupings. In this table, 20 dB are subtracted from the outdoor levels to make them approximately equivalent to indoor levels (it was generally found that the house attenuated outdoor levels by 20 dB and the mobile home attenuated outdoor levels by 19 dB).

The data in Table 9 indicate two strong trends: the offset between helicopter and control levels for equivalency of annoyance varies with site and with the presence of vibrations and rattles. In the tent, which can be considered outdoors, the offset ranges from 3 to 6 dB with 4.5 dB as an average. This result compares favorably with the 0 to 4 dB found by other researchers in the totally outdoor situation.[10] In the mobile home, the offset ranges from 3 to 14 dB with almost 8 dB as an average. This increased offset may be due to the ever present low frequency resonance excited by the helicopter.

The house is where the most interesting data developed. Here the offset clearly divides based on the presence of vibrations and rattles. With no vibrations or rattles, the helicopter is equal to or less annoying than the control for the same A-weighted SELs. However, when a little vibration or rattling is present, the helicopter SEL offset is on the order of 12 dB; when a lot of vibration is present the offset exceeds 20 dB.

Table 9

Decibel Offsets as a Function of Location, Vibration/Rattle Level, and Control Level to Establish Equivalency

Control SEL (Bin Center), dB*	Tent**	Mobile Home	House Liv-Din		
			Vib. 1	Vib. 2	Vib. 3
62	+5	ND***	ND	ND	ND
66	+6	S‡	-1	ND	ND
70	+3	+3	-20	+9	+H‡‡
74	+6	+6	-2	+9	+H
78	+4	+14	+6	+13	+H
82	+4	+7	S	+16	+H
86	+4	+8	ND	S	+17
Average	4.6	7.6	-4.2	11.7	H

*Control level 4-dB-wide bin center value.
**Control levels in the tent were 20 dB higher to account for the nominal A-weighted attenuation of helicopter noise by the house or mobile home.
***Not enough data to construct a regression line (only 1 or 2 points).
‡Too much scatter to have a meaningful regression line.
‡‡Data saturated at the high end with at least +20 dB required to establish equivalency.

[10] L. C. Sutherland and R. E. Burke, *Annoyance, Loudness, and Measurement of Repetitive Type Impulsive Noise Sources*, EPA-550/9-79-103 (U.S. Environmental Protection Agency, November 1979).

Rattle and Spectrum Versus Distance

It appears that if A-weighting is to be used to assess helicopter noise, it is valid only when the helicopter does not excite noticeable vibrations or rattles. Tables 10 and 11 show the frequency of occurrence of the three subjective vibration/rattle levels as a function of slant distance. For this test (this house and a UH-1H aircraft), the slant distance would have had to be 1000 ft or greater to reasonably use A-weighting and avoid the vibration/rattle region.

The data were examined to see if the maximums 1/2 second, 1/3 octave spectrum would correlate with the level of vibration in the house. Only the 200- and 500-ft slant distances had sufficient occurrences of all vibration levels at the identical indoor helicopter SEL. For the 200-ft slant distance, there were several occurrences of a 70-dB A-weighted SEL for the helicopter in the house at all three vibration levels. The energy average maximum 1/2 second, 1/3 octave indoor spectra are shown in Figure 17. Figure 18 shows the corresponding outdoor data (measured on the 30-ft pole) for these specific events. Figures 19 and 20 illustrate similar data for a 500-ft slant distance; but in this case the indoor SEL is 68 dB.

The data do not indicate a clear correlation between 1/3 octave spectrum and the level of the rattle. While the incidence and magnitude of the rattle must be related to the noise stimulus, the maximum 1/2 second spectrum appears to be inadequate to describe this relation. It may be that other portions of the flyover or a narrow band analysis are required to understand the relationship.

An Alternative Hypothesis to Vibration

Can there be other reasons why A-weighting fails to work when vibrations and rattles are perceptible? One hypothesis is the "overhead theory." This theory states that an aircraft flying overhead at a low altitude generates fear which is translated into increased annoyance.

This hypothesis was examined. Of course, an aircraft overhead at low altitudes must be at a short slant distance and will usually generate vibrations and rattles (Tables 10 and 11). To separate the "overhead" factor from the "distance" factor, the data were split by the aircraft being overhead (100 or 200 ft AGL) versus flying to the side (400, 950, and 1980 ft at 300 ft AGL). To make a valid comparison, these data were generated with the vibration level held constant. Figure 21 illustrates a typical example for the house dining room, vibration level 2, and a control SEL range of 72 to 76 dB. Clearly, the overhead data in this figure indicate no increase in annoyance compared with the sideline data. In fact, this negative finding is the general trend and the other, similar figures have not been included for the sake of brevity. It was concluded that, in this test, whether or not the aircraft was overhead was not a factor in the subject's annoyance judgments.

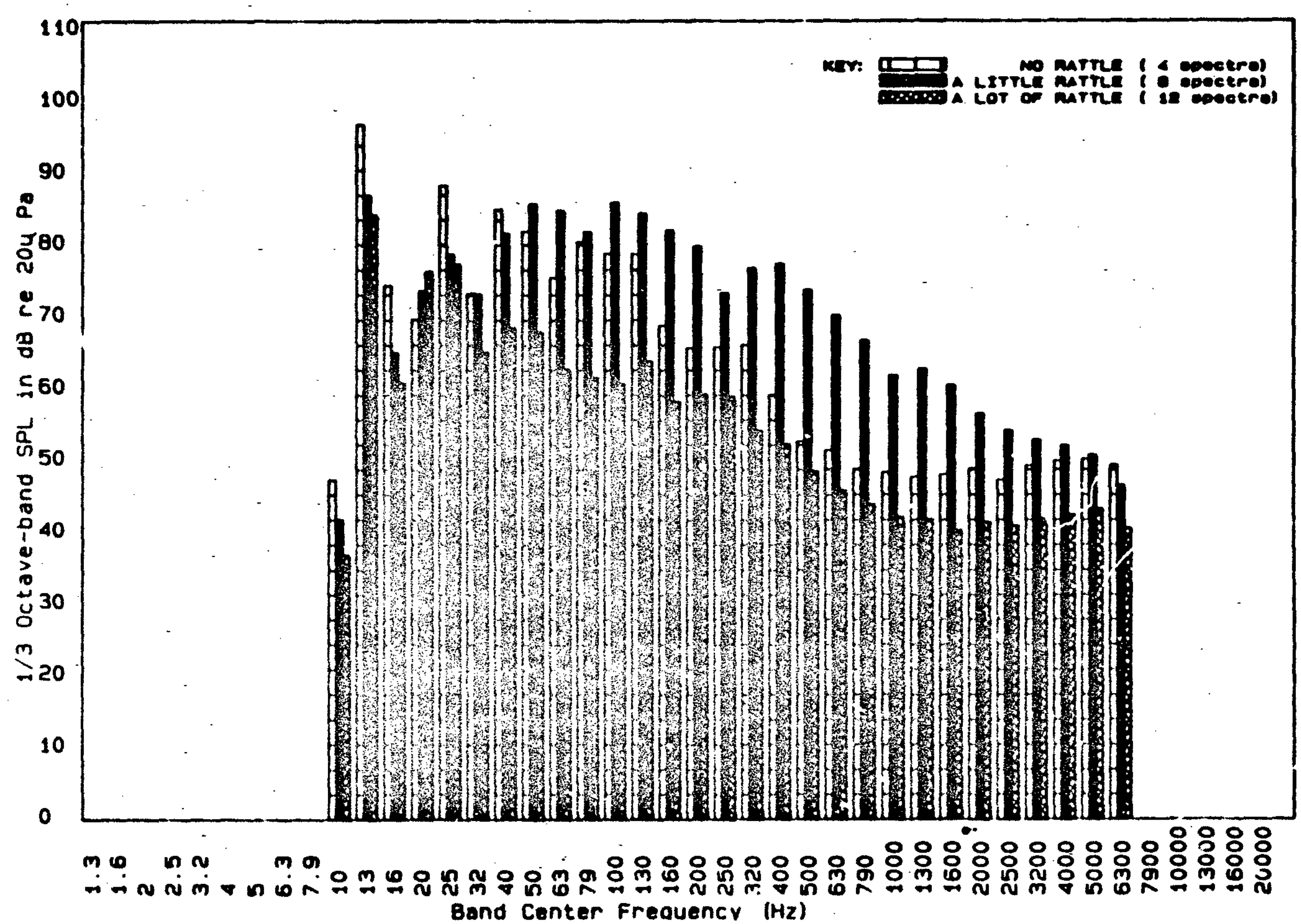


Figure 17. **1/3 octave band SPL vs. frequency inside the house for the maximum A-weighted 1/2 second inside the house. The A-weighted SEL inside the house was 70 dB in all cases.**

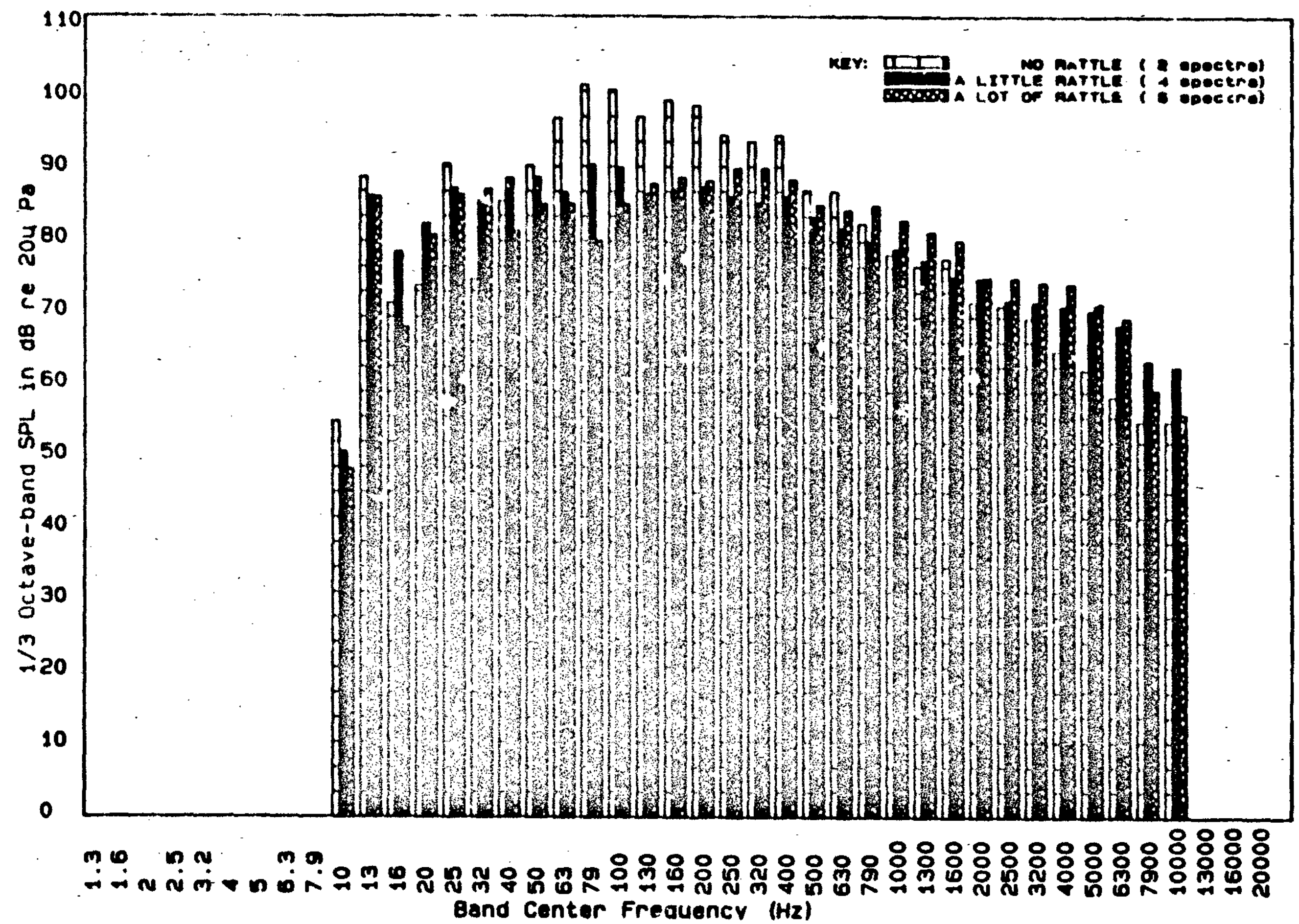


Figure 18. 1/3 octave band SPL vs. frequency outside the house on a 30-ft pole for the maximum A-weighted 1/2 second outside the house. The A-weighted SEL inside the house was 70 dB in all cases.

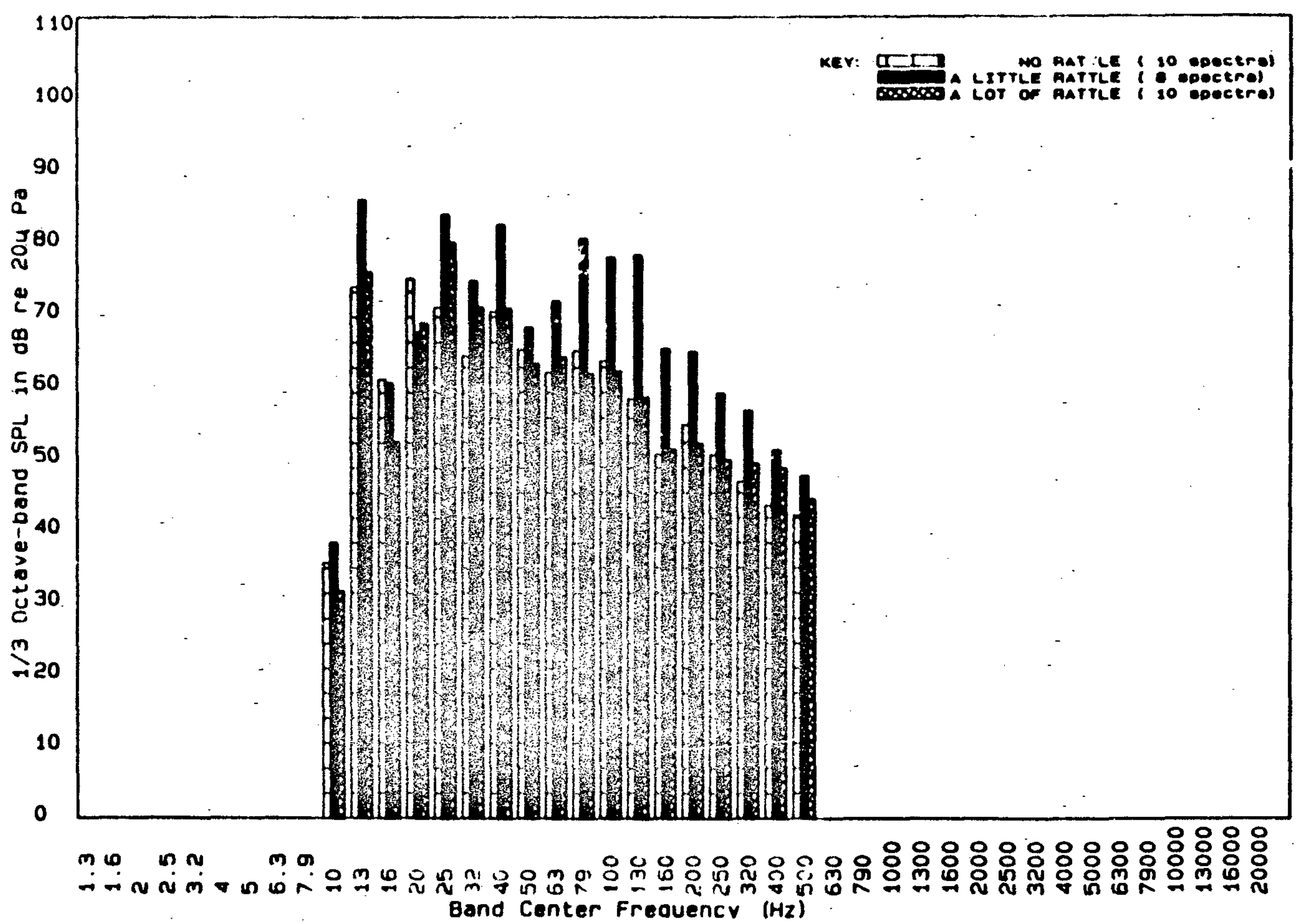


Figure 19. 1/3 octave band SPL vs. frequency inside the house for the maximum A-weighted 1/2 second inside the house. The A-weighted SEL inside the house was 68 dB in all cases.

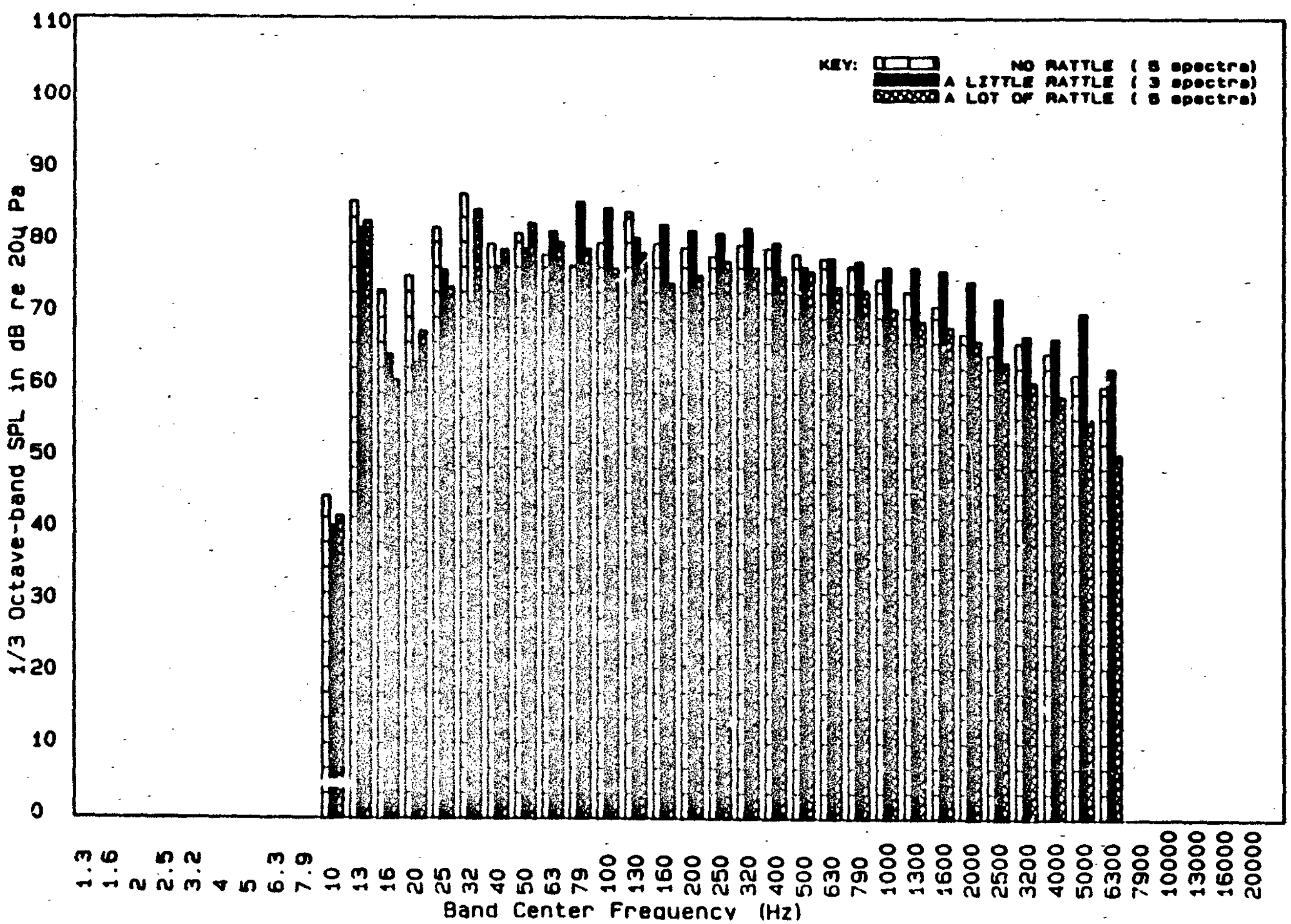


Figure 20. 1/3 octave band SPL vs. frequency outside the house on a 30-ft pole for the maximum A-weighted 1/2 second outside the house. The A-weighted SEL inside the house was 68 dB in all cases.

Table 10

Subjective Vibration/Rattle Levels as a Function of Slant Distance in the Dining Room (Number of Occurrences)

Slant Distance (ft)	Vibration/Rattle Level* 1	2	3	Total
100	9	14	33	56
200	23	39	49	111
500	48	58	6	112
1000	72	15	0	87
2000	47	0	0	47
Total	199	126	88	413

*Levels 1, 2, and 3 correspond to the USA-CERL researchers' judgments of "none," "a little," or "a lot," respectively.

Table 11

Subjective Vibration/Rattle Levels as a Function of Slant Distance in the Living Room (Number of Occurrences)

Slant Distance (ft)	Vibration/Rattle Level* 1	2	3	Total
100	3	13	40	56
200	3	31	74	108
500	42	22	45	109
1000	48	28	6	82
2000	44	6	1	51
Total	140	100	166	406

*Levels 1, 2, and 3 correspond to the USA-CERL researchers' judgments of "none," "a little," or "a lot," respectively.

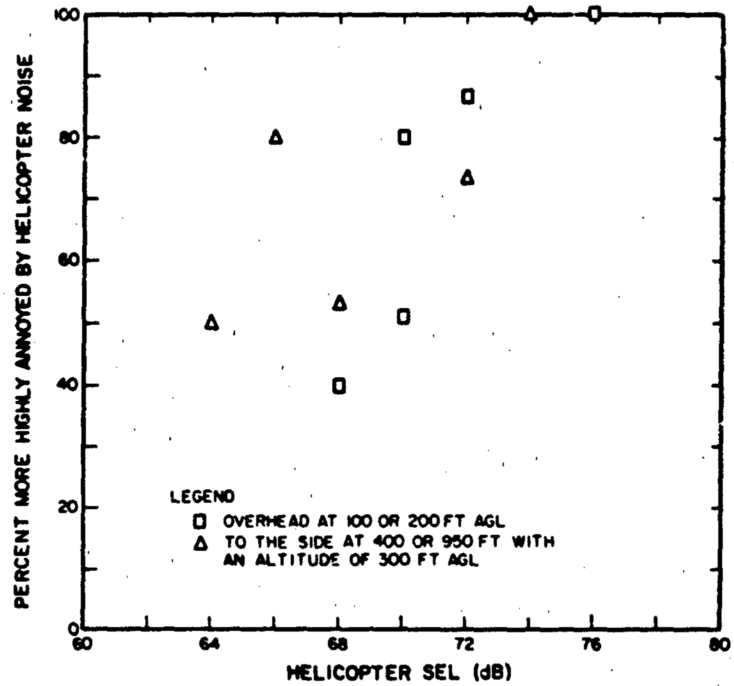


Figure 21. Dining room responses for a subjective vibration level 2 and a control SEL range from 72 to 76 dB. The data are split by aircraft overhead versus to the side.

Can Alternative Measurement Sites or Measures Clarify Results?

The A-weighted data in Appendix D measured indoors divide distinctly into three groups, depending on the USA-CERL researchers' subjective evaluations of the rattle present. Since the response data divided into three groups rather than collapsing into one group when the helicopter noise was A-weighted, it was decided to compare the indoor responses using a C-weighted measure of the noise rather than the A-weighted data contained in Appendix D. Appendix E contains the C-weighted data. The general results in Appendix E for the C-weighted indoor data show that C-weighting offers no improvement over the A-weighted liv-din data; the data still divide into three groups.

In yet another effort to get the indoor liv-din data to collapse into one group, outdoor A-weighted and C-weighted helicopter data were used in conjunction with the liv-din responses. These data are also in Appendix E. (For brevity, the outdoor tent data were used as pure outdoor data; significant A-weighted or C-weighted attenuation is not expected through the canvas walls and ceiling of the tent when the noise source is a helicopter). The general results evident in Appendix E for both A-weighted and C-weighted data are that the vibration groups 1 and 2 tend to come together, but that the high vibration and rattle data (group 3) remain very distinct from the other two groups. Again, as with the indoor data, the C-weighted data offer no improvement over the A-weighted data. Neither A-weighting nor C-weighting appears capable of fully describing the responses when high levels of vibration and rattle are present.

That C-weighting offers no improvement over A-weighting is further emphasized by the data in Appendix F. Here, the liv-din subjective responses (percentage finding the helicopter noise more annoying compared with a 500-Hz octave band white noise control) are plotted versus the difference between the C-weighted and A-weighted SELs (C-A). Two sets of acoustical data are included: indoor liv-din helicopter noise data and data gathered by the microphone in the tent. In general, the responses do not vary with changes in the C-A value; however, they do divide clearly based on the three vibration/rattle categories.

A-Weighted Results: Summary

The outdoor A-weighted helicopter data can be compared directly with the indoor A-weighted control by compensating for the farmhouse's attenuation of A-weighted helicopter noise, which was nearly 20 dB. Table 12 compares the outdoor A-weighted group 1 and 2 data for when 50 percent of the subjects found the helicopter more annoying and 50 percent found the control noise more annoying. This table lists the indoor bin center white noise control level, the outdoor A-weighted helicopter data 50/50 point, and the difference minus 20 dB to account for the outdoor-to-indoor house attenuation of the A-weighted helicopter noise. As before, the group 3 data remain far offscale, indicating a large offset or penalty is required--at least 20 dB. All outdoor A-weighted data in Table 12 compare very favorably with the indoor A-weighted data in Table 9.

The general result for these group 1 and 2 vibration and rattle level responses with A-weighted helicopter noise measured indoors or outdoors is that the offset or adjustment required for helicopter noise assessment is on the order of 0 dB for no rattle and 10 dB for a little rattle. These offsets are averages; Tables 9 and 12 show that the offsets tend to increase with noise level. Table 13 lists the offset averages for the tent, mobile home, and vibration level 1 and 2 data in the house (liv-din). Taken together, these overall data indicate that helicopter noise requires an offset or adjustment of perhaps 5 to 10 dB indoors when a little vibration or rattling is present or when there is no rattle but the helicopter SEL is high (above about 90 dB). When the helicopter SEL is lower than about 90 dB and there is no vibration or rattling, there is no offset. Outdoors, the offset is at most about 4 dB. When high levels of vibration and rattle are present, the offset is very large--on the order of 20 dB or more. Table 14 provides summary results of decibel offset or adjustment for use in environmental assessment.

Table 12

Decibel Offsets for Outdoor-Measured Helicopter A-Weighted SELs* in the House (Liv-din)

Control SEL (Bin center)	Vibrat'on Group 1		Vibration Group 2	
	SEL	Offset	SEL	Offset
62	87	-5	ND**	-
66	91	-5	ND	-
70	101-1/2	-10-1/2	84-1/2	+6
74	100-1/2	-6-1/2	82-1/2	+11-1/2
78	92	+6	86	+12
82	95-1/2	6-1/2	ND	-
86	ND	-	ND	-
Average		-2.4		9.8

*Twenty dB are subtracted from the outdoor SEL to account for building attentuation.
**ND means insufficient data.

Table 13

Average A-Weighted Decibel Offsets by Subject Group, Microphone Location, and Vibration Level

	Tent*	Mobile Home*	House Liv-din Vib. 1 Inside*	Vib. 1 Outside**	Vib. 2 Inside*	Vib. 2 Outside**
Decibel offset	+4.6	+7.6	-4.2	-2.4	+11.7	+9.8

*Data from Table 9.
**Data from Table 12.

Table 14

Decibel Offset or Adjustment—Summary Results

	Rattle	Outdoor A-Weighted SEL	Offset of Adjustment (dB)	Slant Distance (ft)
a. House				
	None	< 90	0	> 1000
	None	> 90	5-10	> 1000
	A little	All	5-10	> 500
	A lot	All	20	> 500
b. Trailer				
	NA	All	6-10	All
c. Outdoors (Tent)				
	NA	All	0-4	All

5 CONCLUSIONS

Human response is strongly and negatively influenced when the noise induces noticeable vibrations and rattles. However, A-weighting is insufficient to fully characterize this response. C-weighting is no improvement over A-weighting; neither can properly assess human response when the helicopter noise excites high levels of vibration and rattle.

When little vibration or rattling is induced by the helicopter or there are no rattles but the helicopter SEL exceeds about 90 dB, the offset or adjustment for proper assessment of helicopter noise appears to be on the order of 5 to 10 dB for subjects indoors. Outdoors, the offset or adjustment drops to about 4 dB or less. When no vibration or rattling is induced and the helicopter SEL is less than about 90 dB, the offset is zero. When the helicopter induces high levels of vibration or rattles, the indoor offset or adjustment is on the order of 20 dB or more.

The data in Tables 10 and 11 show that the presence or absence of high levels of helicopter-noise-induced vibrations and rattles is strongly dependent on the helicopter's slant distance. In this experiment, slant distances shorter than 500 ft virtually ensured high levels of helicopter-noise-induced vibrations and rattles whereas slant distances in excess of 1000 ft virtually ensured little or no such vibrations or rattles.

Overall, this experiment indicates the need for an offset or adjustment when A-weighting is used to assess indoor human response to helicopter noise. On average, this offset or adjustment appears to be on the order of 5 dB or more. Further, the use of A-weighted assessment techniques such as Day-Night Average Sound Level is invalid when high levels of noise-induced vibration and rattle are present. The data indicate that no housing or noise-sensitive land use should be in zones where helicopter noise can induce high levels of vibration or rattle because of the large offset (20 dB). For the Huey aircraft in this experiment, the no-housing zone boundary lies between 500 and 1000 ft. Thus, these data indicate, at least for the Huey, that no housing or noise-sensitive land use should be located within 500 ft (slant distance) of general helicopter operations and that the region between 500- and 1000-ft slant distance must be examined carefully on a case-by-case basis. Beyond 1000 ft, there should be an adjustment of perhaps 5 dB. Since the Huey makes about 5 dB more noise when landing compared to level flyover or takeoff, the no-housing distance in the vicinity of a heliport for a Huey is closer to 900 ft with the discretionary distance extending to about 1700 ft.

METRIC CONVERSION FACTORS

1 in. = 2.54 cm
1 ft = 0.305 m
1 mi = 1.61 km

APPENDIX A:

DATA FORMS

Forms used in collecting data for the study are shown as Figures A1, answer sheets for the two different orders of control presentation; A2, microphone data sheets; A3, velocity data sheets; A4, tape recorder data form; A5, theodolite data form; A6, subjective vibration/rattle data sheet--USA-CERL researcher; and A7, weather conditions.

M T T am, W F pm

SUBJECT RESPONSE FORM

NAME (please print) ______________________ SET NUMBER ______________

LOCATION (please circle): 1 Outside 2 Mobile home 3 House living room 4 House dining room

DAY and TIME (please circle): 1 Monday 2 Tuesday 3 Wednesday 4 Thursday 5 Friday 1 AM / 2 PM

TRIAL NUMBER	CIRCLE THE NOISE THAT WAS MORE ANNOYING		HOW HARD WAS IT TO MAKE UP YOUR MIND?				
	(RED) A	(YELLOW) B	very easy		in between		very hard
PRACTICE	1	2	1	2	3	4	5
PRACTICE	1	2	1	2	3	4	5
PRACTICE	HELICOPTER	COMPARISON	1	2	3	4	5
1	HELICOPTER	COMPARISON	1	2	3	4	5
2	HELICOPTER	COMPARISON	1	2	3	4	5
3	HELICOPTER	COMPARISON	1	2	3	4	5
4	HELICOPTER	COMPARISON	1	2	3	4	5
5	HELICOPTER	COMPARISON	1	2	3	4	5
6	HELICOPTER	COMPARISON	1	2	3	4	5
7	HELICOPTER	COMPARISON	1	2	3	4	5
8	HELICOPTER	COMPARISON	1	2	3	4	5
9	COMPARISON	HELICOPTER	1	2	3	4	5
10	COMPARISON	HELICOPTER	1	2	3	4	5
11	COMPARISON	HELICOPTER	1	2	3	4	5
12	COMPARISON	HELICPOTER	1	2	3	4	5
13	COMPARISON	HELICOPTER	1	2	3	4	5
14	COMPARISON	HELICOPTER	1	2	3	4	5
15	COMPARISON	HELICOPTER	1	2	3	4	5
16	COMPARISON	HELICOPTER	1	2	3	4	5

Figure A1. Subject response form.

M T T am, W F pm

NAME (please print) ______________________ SET NUMBER ____________

TRIAL NUMBER	CIRCLE THE NOISE THAT WAS MORE ANNOYING		HOW HARD WAS IT TO MAKE UP YOUR MIND?				
	(RED) A	(YELLOW) B	very easy		in between		very hard
17	HELICOPTER	COMPARISON	1	2	3	4	5
18	HELICOPTER	COMPARISON	1	2	3	4	5
19	HELICOPTER	COMPARISON	1	2	3	4	5
20	HELICOPTER	COMPARISON	1	2	3	4	5
21	HELICOPTER	COMPARISON	1	2	3	4	5
22	HELICOPTER	COMPARISON	1	2	3	4	5
23	HELICOPTER	COMPARISON	1	2	3	4	5
24	COMPARISON	HELICOPTER	1	2	3	4	5
25	COMPARISON	HELICOPTER	1	2	3	4	5
26	COMPARISON	HELICOPTER	1	2	3	4	5
27	COMPARISON	HELICOPTER	1	2	3	4	5
28	COMPARISON	HELICOPTER	1	2	3	4	5
29	COMPARISON	HELICOPTER	1	2	3	4	5
30	COMPARISON	HELICOPTER	1	2	3	4	5
31	COMPARISON	HELICOPTER	1	2	3	4	5
32	HELICOPTER	COMPARISON	1	2	3	4	5
33	HELICOPTER	COMPARISON	1	2	3	4	5
34	HELICOPTER	COMPARISON	1	2	3	4	5
35	HELICOPTER	COMPARISON	1	2	3	4	5
36	HELICOPTER	COMPARISON	1	2	3	4	5
37	HELICOPTER	COMPARISON	1	2	3	4	5
38	HELICOPTER	COMPARISON	1	2	3	4	5
39	HELICOPTER	COMPARISON	1	2	3	4	5
40	COMPARISON	HELICOPTER	1	2	3	4	5
41	COMPARISON	HELICOPTER	1	2	3	4	5
42	COMPARISON	HELICOPTER	1	2	3	4	5
43	COMPARISON	HELICOPTER	1	2	3	4	5
44	COMPARISON	HELICOPTER	1	2	3	4	5
45	COMPARISON	HELICOPTER	1	2	3	4	5
46	COMPARISON	HELICOPTER	1	2	3	4	5

Figure A1. (Cont'd).

W F am, M T T pm

SUBJECT RESPONSE FORM

NAME (please print) ______________________ SET NUMBER ____________

LOCATION (please circle): 1 Outside 2 Mobile home 3 House living room 4 House dining room

DAY and TIME (please circle): 1 Monday 2 Tuesday 3 Wednesday 4 Thursday 5 Friday 1 AM / 2 PM

TRIAL NUMBER	CIRCLE THE NOISE THAT WAS MORE ANNOYING		HOW HARD WAS IT TO MAKE UP YOUR MIND?				
	(RED) A	(YELLOW) B	very easy		in between		very hard
PRACTICE	1	2	1	2	3	4	5
PRACTICE	1	2	1	2	3	4	5
PRACTICE	COMPARISON	HELICOPTER	1	2	3	4	5
1	COMPARISON	HELICOPTER	1	2	3	4	5
2	COMPARISON	HELICOPTER	1	2	3	4	[illegible]
3	COMPARISON	HELICOPTER	1	2	3	4	[illegible]
4	COMPARISON	HELICOPTER	1	2	3	4	5
5	COMPARISON	HELICOPTER	1	2	3	4	5
6	COMPARISON	HELICOPTER	1	2	3	4	5
7	COMPARISON	HELICOPTER	1	2	3	4	5
8	COMPARISON	HELICOPTER	1	2	3	4	5
9	HELICOPTER	COMPARISON	1	2	3	4	5
10	HELICOPTER	COMPARISON	1	2	3	4	5
11	HELICOPTER	COMPARISON	1	2	3	4	5
12	HELICOPTER	COMPARISON	1	2	3	4	5
13	HELICOPTER	COMPARISON	1	2	3	4	5
14	HELICOPTER	COMPARISON	1	2	3	4	5
15	HELICOPTER	COMPARISON	1	2	3	4	5
16	HELICOPTER	COMPARISON	1	2	3	4	5
17	COMPARISON	HELICOPTER	1	2	3	4	5
18	COMPARISON	HELICOPTER	1	2	3	4	5
19	COMPARISON	HELICOPTER	1	2	3	4	5
20	COMPARISON	HELICOPTER	1	2	3	4	5
21	COMPARISON	HELICOPTER	1	2	3	4	5
22	COMPARISON	HELICOPTER	1	2	3	4	5
23	COMPARISON	HELICOPTER	1	2	3	4	5

Figure A1. (Cont'd).

W F am, M T T pm

NAME (please print) ______________________ SET NUMBER ______________

TRIAL NUMBER	CIRCLE THE NOISE THAT WAS MORE ANNOYING		HOW HARD WAS IT TO MAKE UP YOUR MIND?				
	(RED) A	(YELLOW) B	very easy		in between		very hard
24	HELICOPTER	COMPARISON	1	2	3	4	5
25	HELICOPTER	COMPARISON	1	2	3	4	5
26	HELICOPTER	COMPARISON	1	2	3	4	5
27	HELICOPTER	COMPARISON	1	2	3	4	5
28	HELICOPTER	COMPARISON	1	2	3	4	5
29	HELICOPTER	COMPARISON	1	2	3	4	5
30	HELICOPTER	COMPARISON	1	2	3	4	5
31	HELICOPTER	COMPARISON	1	2	3	4	5
32	COMPARISON	HELICOPTER	1	2	3	4	5
33	COMPARISON	HELICOPTER	1	2	3	4	5
34	COMPARISON	HELICOPTER	1	2	3	4	5
35	COMPARISON	HELICOPTER	1	2	3	4	5
36	COMPARISON	HELICOPTER	1	2	3	4	5
37	COMPARISON	HELICOPTER	1	2	3	4	5
38	COMPARISON	HELICOPTER	1	2	3	4	5
39	COMPARISON	HELICOPTER	1	2	3	4	5
40	HELICOPTER	COMPARISON	1	2	3	4	5
41	HELICOPTER	COMPARISON	1	2	3	4	5
42	HELICOPTER	COMPARISON	1	2	3	4	5
43	HELICOPTER	COMPARISON	1	2	3	4	5
44	HELICOPTER	COMPARISON	1	2	3	4	5
45	HELICOPTER	COMPARISON	1	2	3	4	5
46	HELICOPTER	COMPARISON	1	2	3	4	5

Figure A1. (Cont'd).

MICROPHONE DATA SET ____ DAY __________ AM / PM

DATE TIME

	Time	Living E	Living W	Dining E	Dining W	Mobile E	Mobile W	Outside Group	Outside Truck
Channel									
Mike No.									
Pre-Amp No.									
Amp Type/No									
Gain									
Cal Level									
B Box No.									
Gain Const.									
1 - A									
B									
2 - A									
B									
3 - A									
B									
4 - A									
B									
5 - A									
B									
6 - A									
B									
7 - A									
B									
8 - A									
B									
9 - A									
B									
10 - A									
B									
11 - A									
B									
12 - A									
B									

Figure A2. Microphone data sheets.

MICROPHONE DATA SET ____ DAY ______________ AM / PM
DATE ______________ TIME ________

	Time	Living E	Living W	Dining E	Dining W	Mobile E	Mobile W	Outside Group	Outside Truck
13 - A									
B									
14 - A									
B									
15 - A									
B									
16 - A									
B									
17 - A									
B									
18 - A									
B									
19 - A									
B									
20 - A									
B									
21 - A									
B									
22 - A									
B									
23 - A									
B									
24 - A									
B									
25 - A									
B									
26 - A									
B									
27 - A									
B									
28 - A									
B									
29 - A									
B									

Figure A2. (Cont'd).

MICROPHONE DATA SET ______ DAY ______________ AM / PM

DATE ______________ TIME __________

	Time	Living E	Living W	Dining E	Dining W	Mobile E	Mobile W	Outside Group	Outside Truck
30 - A									
B									
31 - A									
B									
32 - A									
B									
33 - A									
B									
34 - A									
B									
35 - A									
B									
36 - A									
B									
37 - A									
B									
38 - A									
B									
39 - A									
B									
40 - A									
B									
41 - A									
B									
42 - A									
B									
43 - A									
B									
44 - A									
B									
45 - A									
B									
46 - A									
B									

Figure A2. (Cont'd).

VELOCITY DATA SET _____ DAY ____________ AM / PM

DATE _______ TIME _______

	Time	North Wall	South Wall	Mobile Wall	North Window	South Window	Mobile Window
Channel							
Device No.							
Amp. No.							
Gain							
SLM low No.							
Setting							
SLM High No.							
Setting							
Gain Constant							
1-A							
B							
2-A							
B							
3-A							
B							
4-A							
B							
5-A							
B							
6-A							
B							
7-A							
B							
8-A							
B							
9-A							
B							
10-A							
B							
11-A							
B							
12-A							
B							

Figure A3. Velocity data sheets.

VELOCITY DATA SET ________ DAY __________ AM / PM
DATE __________ TIME ______

	Time	North Wall	South Wall	Mobile Wall	North Window	South Window	Mobile Window
13 - A							
B							
14 - A							
B							
15 - A							
B							
16 - A							
B							
17 - A							
B							
18 - A							
B							
19 - A							
B							
20 - A							
B							
21 - A							
B							
22 - A							
B							
23 - A							
B							
24 - A							
B							
25 - A							
B							
26 - A							
B							
27 - A							
B							
28 - A							
B							
29 - A							
B							

Figure A3. (Cont'd).

VELOCITY DATA SET ____________ DAY ______________ AM / PM
DATE ______________ TIME ________

	Time	North Wall	South Wall	Mobile Wall	North Window	South Window	Mobile Window
30 - A							
B							
31 - A							
B							
32 - A							
B							
33 - A							
B							
34 - A							
B							
35 - A							
B							
36 - A							
B							
37 - A							
B							
38 - A							
B							
39 - A							
B							
40 - A							
B							
41 - A							
B							
42 - A							
B							
43 - A							
B							
44 - A							
B							
45 - A							
B							
46 - A							
B							

Figure A3. (Cont'd).

TAPE RECORDER DATA						DAY ______	AM / PM			
SET						DATE ______	Time			
RUN		M, T, Th W, F	AM PM	Tape Counter	NEFF	Mike Atten.	Accel. Atten.	Velocity Atten.	W, F M, T, Th	AM PM
1	200 N	Red			26	18	18	0		Yellow
2	2000 S	Red			26	0	0	0		Yellow
3	200 N	Red			26	18	18	0		Yellow
4	1000 S	Red			26	6	6	0		Yellow
5	500 N	Red			26	12	12	0		Yellow
6	200 S	Red			26	18	18	0		Yellow
7	100 N	Red			26	20	20	0		Yellow
8	200 S	Red			26	18	18	0		Yellow
9	500 N		Yellow		26	12	12	0	Red	
10	1000 S		Yellow		26	6	6	0	Red	
11	100 N		Yellow		26	20	20	0	Red	
12	500 S		Yellow		26	12	12	0	Red	
13	1000 N		Yellow		26	6	6	0	Red	
14	500 S		Yellow		26	12	12	0	Red	
15	500 N		Yellow		26	12	12	0	Red	
16	200 S		Yellow		26	18	18	0	Red	
17	200 N	Red			26	18	18	0		Yellow
18	100 S	Red			26	20	20	0		Yellow
19	200 N	Red			26	18	18	0		Yellow
20	500 S	Red			26	12	12	0		Yellow
21	2000 N	Red			26	0	0	0		Yellow
22	2000 S	Red			26	0	0	0		Yellow
23	1000 N	Red			26	6	6	0		Yellow
24	500 S		Yellow		26	12	12	0	Red	
25	200 N		Yellow		26	18	18	0	Red	
26	1000 S		Yellow		26	6	6	0	Red	
27	1000 N		Yellow		26	6	6	0	Red	
28	200 S		Yellow		26	18	18	0	Red	
29	2000 N		Yellow		26	0	0	0	Red	
30	1000 S		Yellow		26	6	6	0	Red	
31	500 N		Yellow		26	12	12	0	Red	
32	100 S	Red			26	20	20	0		Yellow
33	200 N	Red			26	18	18	0		Yellow
34	500 S	Red			26	12	12	0		Yellow
35	1000 N	Red			26	6	6	0		Yellow
36	2000 S	Red			26	0	0	0		Yellow
37	500 N	Red			26	12	12	0		Yellow
38	200 S	Red			26	18	18	0		Yellow
39	100 N	Red			26	20	20	0		Yellow
40	100 S		Yellow		26	20	20	0	Red	
41	1000 N		Yellow		26	6	6	0	Red	
42	500 S		Yellow		26	12	12	0	Red	
43	500 N		Yellow		26	12	12	0	Red	
44	1000 S		Yellow		26	6	6	0	Red	
45	2000 N		Yellow		26	0	0	0	Red	
46	200 S		Yellow		26	18	18	0	Red	

Figure A4. Tape recorder data sheet.

THEODOLITE OBSERVATIONS Date__________________

Operator ____________________ SET Time ____________

	Time	Run	Aim	Site		Time	Run	Aim	Site
1		200 N	10		24		500 S	25	
2		2000 S	--	--	25		200 N	10	
3		200 N	10		26		1000 S	--	--
4		1000 S	--	--	27		1000 N	--	--
5		500 N	25		28		200 S	10	
6		200 S	10		29		2000 N	--	--
7		100 N	5		30		1000 S	--	--
8		200 S	10		31		500 N	25	
9		500 N	25		32		100 S	5	
10		1000 S	--	--	33		200 N	10	
11		100 N	5		34		500 S	25	
12		500 S	25		35		1000 N	--	--
13		1000 N	--	--	36		2000 S	--	--
14		500 S	25		37		500 N	25	
15		500 N	25		38		200 S	10	
16		200 S	10		39		100 N	5	
17		200 N	10		40		100 S	5	
18		100 S	5		41		1000 N	--	--
19		200 N	10		42		500 S	25	
20		500 S	25		43		500 N	25	
21		2000 N	--	--	44		1000 S	--	--
22		2000 S	--	--	45		2000 N	--	--
23		1000 N	--	--	46		200 S	10	

Figure A5. Theodolite observation sheet.

TEST SITE OBSERVATIONS Date ____________ Time ____________

SET Operator Day AM / PM

	Time	Living-room			Dining-room				Time	Living-room			Dining-room		
		L	M	H	L	M	H			L	M	H	L	M	H
1								24							
2								25							
3								26							
4								27							
5								28							
6								29							
7								30							
8								31							
9								32							
10								33							
11								34							
12								35							
13								36							
14								37							
15								38							
16								39							
17								40							
18								41							
19								42							
20								43							
21								44							
22								45							
23								46							

Figure A6. Test site observation sheet.

WEATHER DATA SET ______					Day ____________ AM / PM Date Time			
Run Number	Time	Wind Speed	Wind Direct.		Run Number	Time	Wind Speed	Wind Direct.
1					24			
2					25			
3					26			
4					27			
5					28			
6					29			
7					30			
8					31			
9					32			
10					33			
11					34			
12					35			
13					36			
14					37			
15					38			
16					39			
17					40			
18					41			
19					42			
20					43			
21					44			
22					45			
23					46			

RELATIVE HUMIDITY:	Wet Bulb	Dry Bulb	Rel. Humidity
Start of test			
Break			
End of test			

Figure A7. Weather data sheet.

APPENDIX B:

HELICOPTER PILOT AND CONTROL FUNCTION FLIP CARDS

The first part of this appendix illustrates the cards used by the pilot on the Monday, Tuesday, and Thursday morning and Wednesday and Friday afternoon sequence. The second part illustrates the alternate sequence. For the control function, the pilot flip cards were augmented with Apple IIe computer and step-attenuator settings. These also are shown in the second set.

Helicopter Test

Construction Engineering Research Laboratory
Champaign, Illinois

October 1983

Pilot's Log

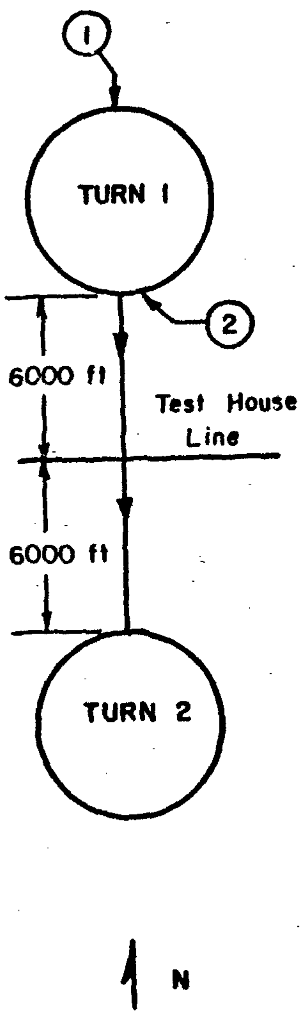
Monday, Tuesday, Thursday mornings
Wednesday and Friday afternoons

Pilot ____________________

Tail Number ______________

Date _____________________

Start Time _______________



Run Number 2

Time ____________

Heading 18

Red -- 2000 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

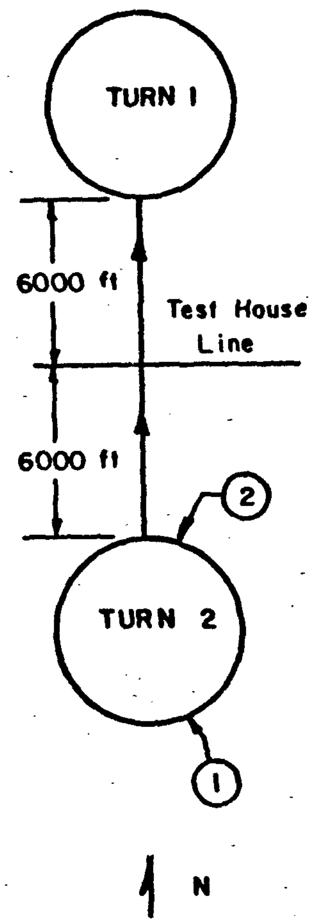
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Orange -- 0 ft

   200 ft AGL



Run Number 1

Time ____________

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

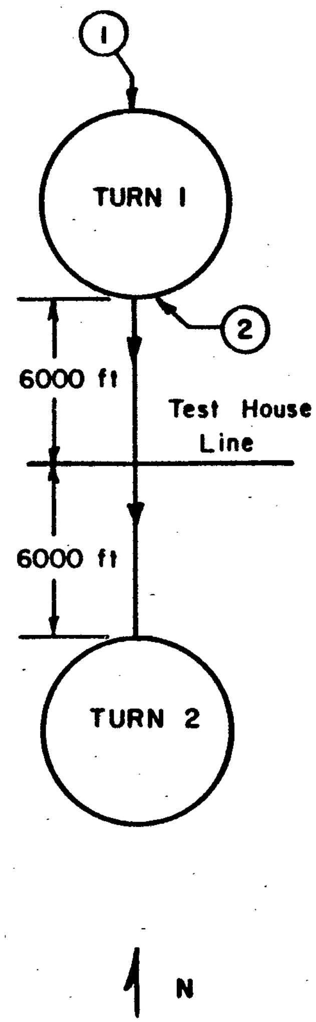
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Red -- 2000 ft

   300 ft AGL



Run Number 4

Time ______

Heading 18

Yellow -- 1000 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

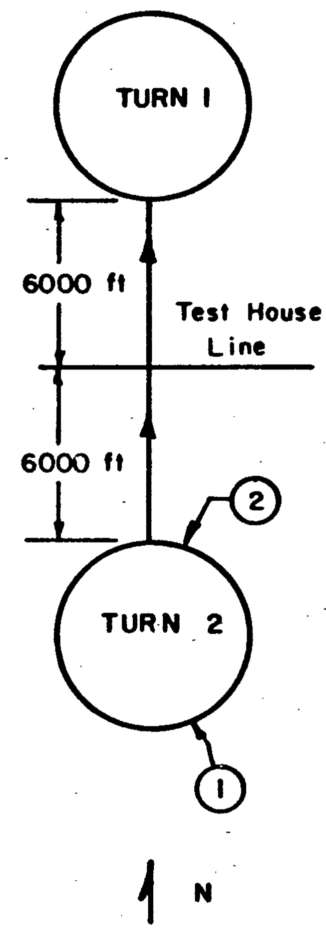
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   White -- 400 ft

   300 ft AGL



Run Number 3

Time ______

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

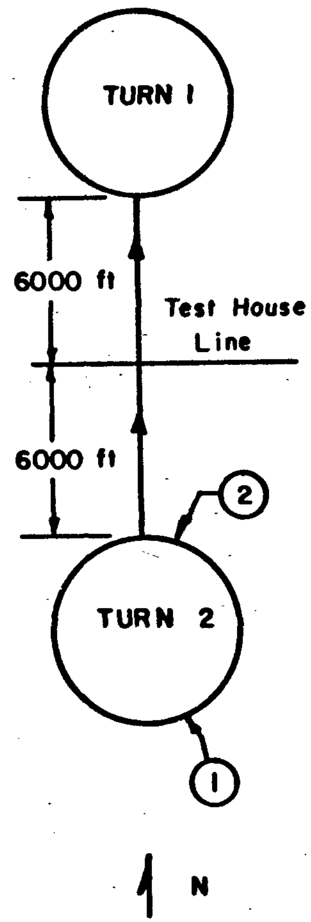
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Yellow -- 1000 ft

   300 ft AGL



Run Number 5

Time ________

Heading 36

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

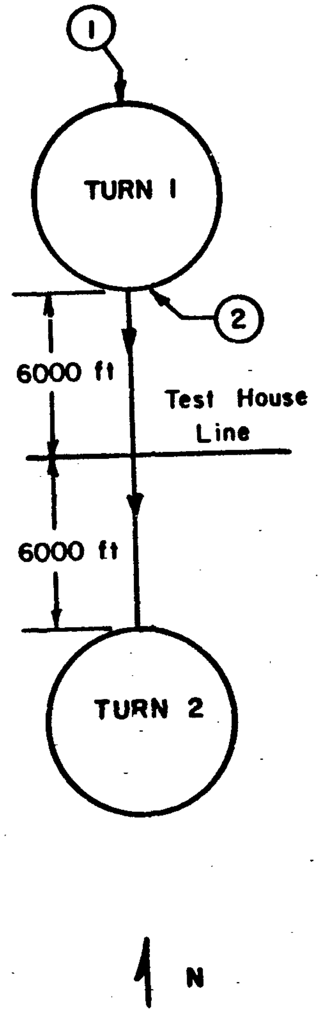
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Orange -- 0 ft

   2 00 ft AGL



Run number 6

Time ________

Heading 18

Orange -- 0 ft

2 00 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

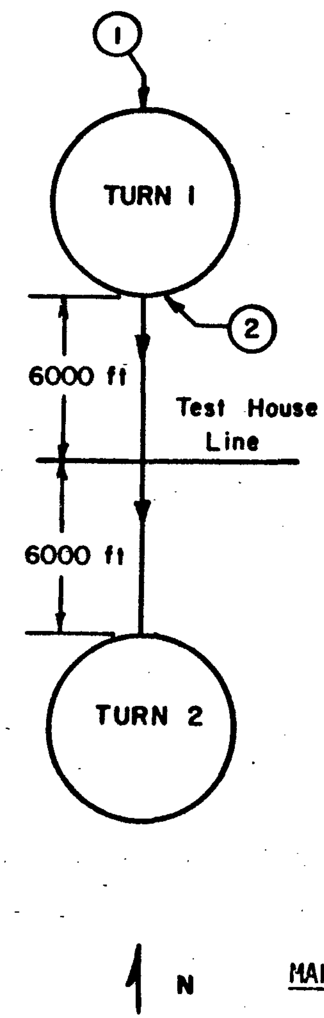
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Orange -- 0 ft

   100 ft AGL



Run Number 8

Time ____________

Heading 18

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

2. Call when 6000 ft from Test House Line.

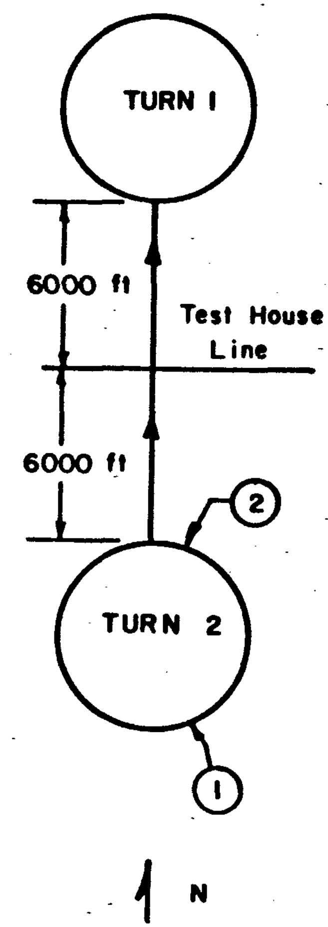
   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

Heading 36

White -- 400 ft

300 ft AGL

MAKE 1EXTRA LOOP OF TURN 2 AND THEN START RUN 9.



Run Number 7

Time ____________

Heading 36

Orange -- 0 ft

100 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

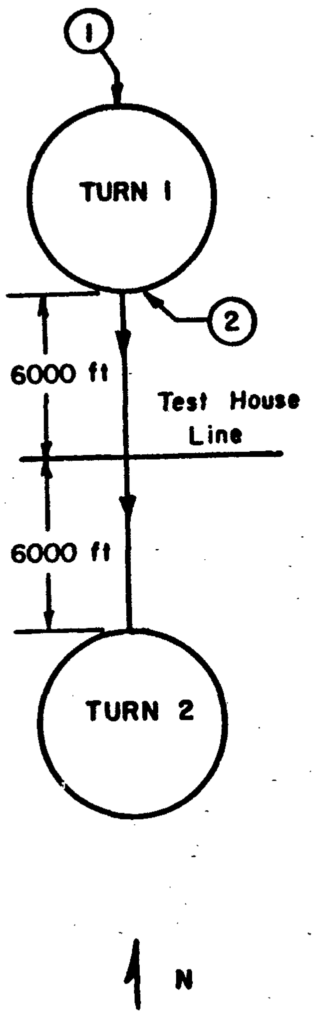
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

Heading 18

Orange -- 0 ft

200 ft AGL



Run Number 10

Time ______

Heading 18

Yellow -- 1000 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

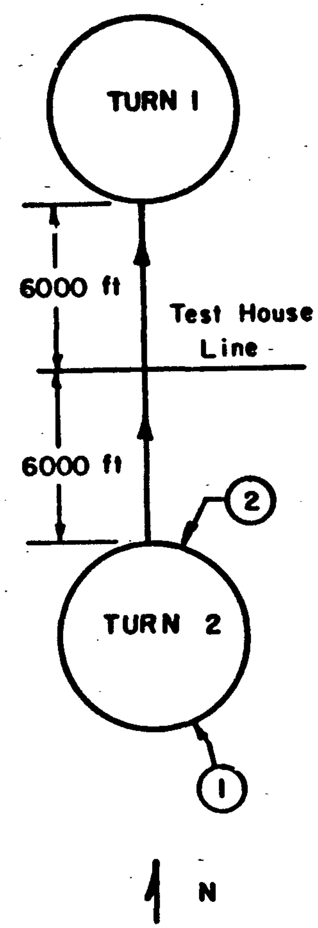
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

Heading 36

Orange -- 0 ft

100 ft AGL



Run Number 9

Time ______

Heading 36

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

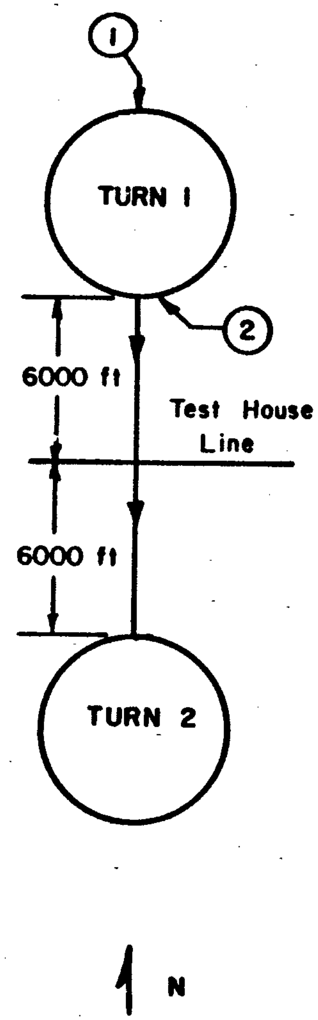
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

Heading 18

Yellow -- 1000 ft

300 ft AGL



Run Number 12

Time ________

Heading 18

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

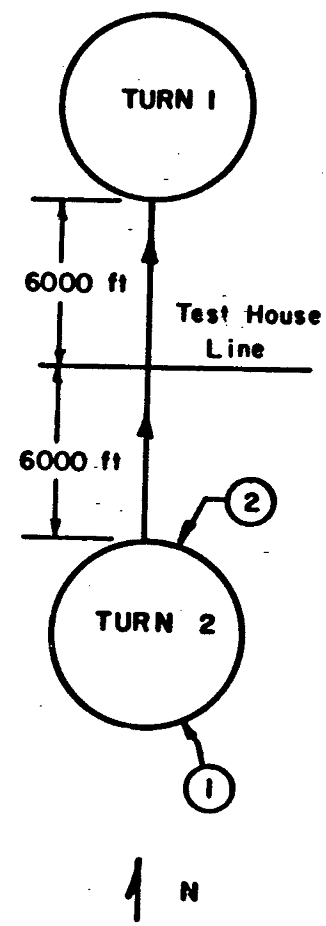
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Yellow -- 1000 ft

   300 ft AGL



Run Number 11

Time ________

Heading 36

Orange -- 0 ft

100 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

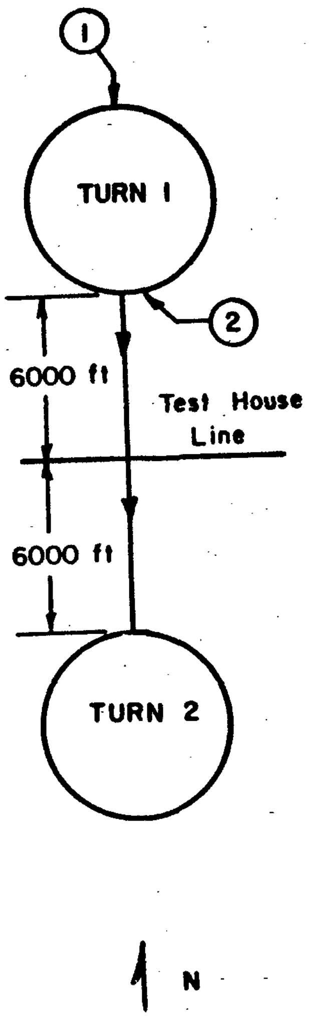
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   White -- 400 ft

   300 ft AGL



Run Number 14

Time ______

Heading 18

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

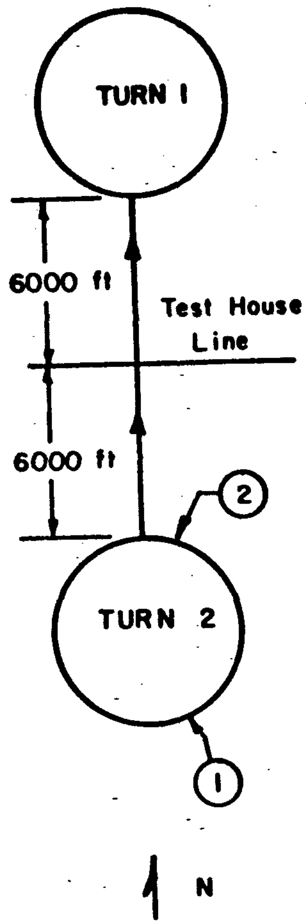
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   White -- 400 ft

   300 ft AGL



Run Number 13

Time ______

Heading 36

Yellow -- 1000 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

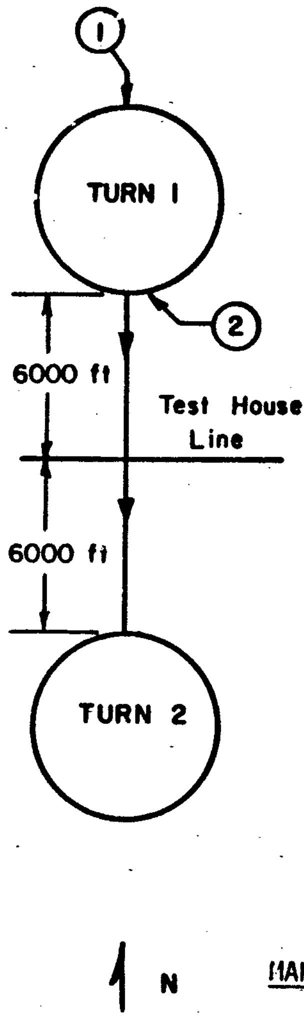
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   White -- 400 ft

   300 ft AGL



Run Number 16

Time ______

Heading 18

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

2. Call when 6000 ft from Test House Line.

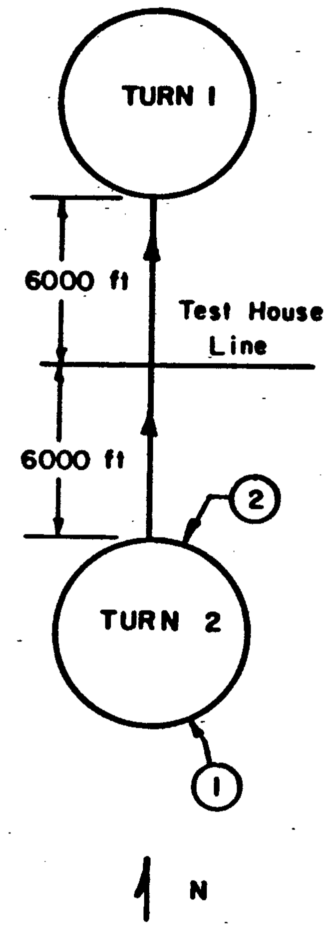
   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Orange -- 0 ft

   200 ft AGL

MAKE 1 EXTRA LOOP OF TURN 2 AND THEN START RUN 17.



Run Number 15

Time ______

Heading 36

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

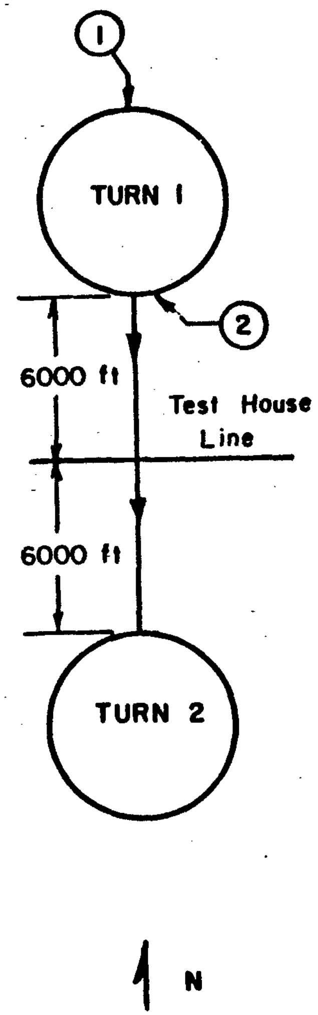
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Orange -- 0 ft

   200 ft AGL



Run Number 18

Time ______

Heading 18

Orange -- 0 ft

100 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

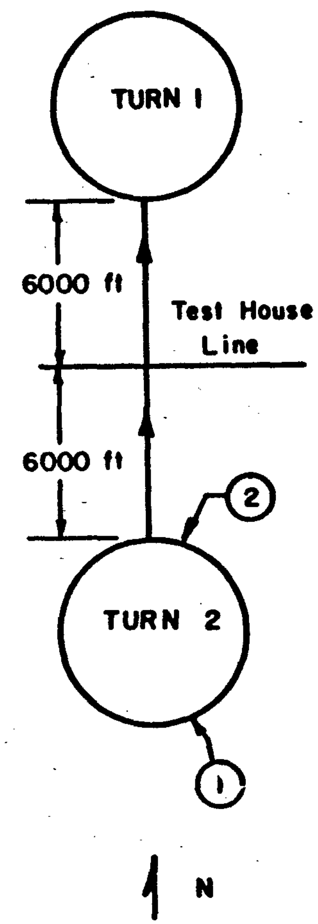
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Orange-- 0 ft

   200 ft AGL



Run Number 17

Time ______

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

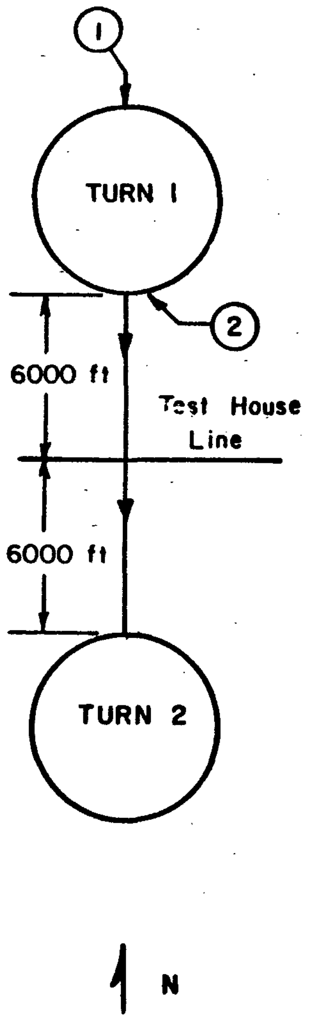
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Orange -- 0 ft

   100 ft AGL



Run Number 20

Time ____________

Heading 18

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

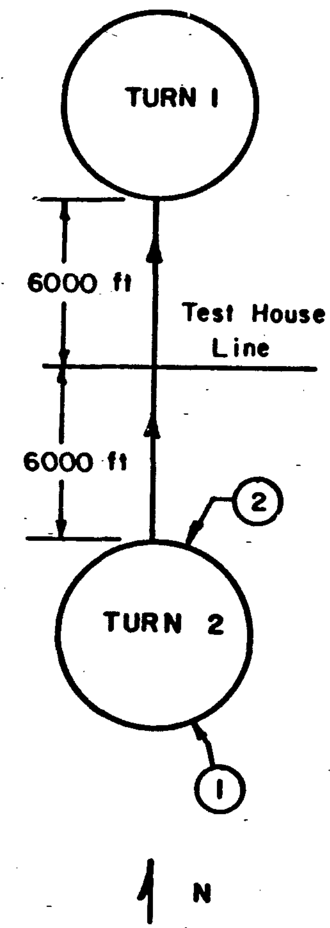
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Red -- 2000 ft

   300 ft AGL



Run Number 19

Time ____________

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

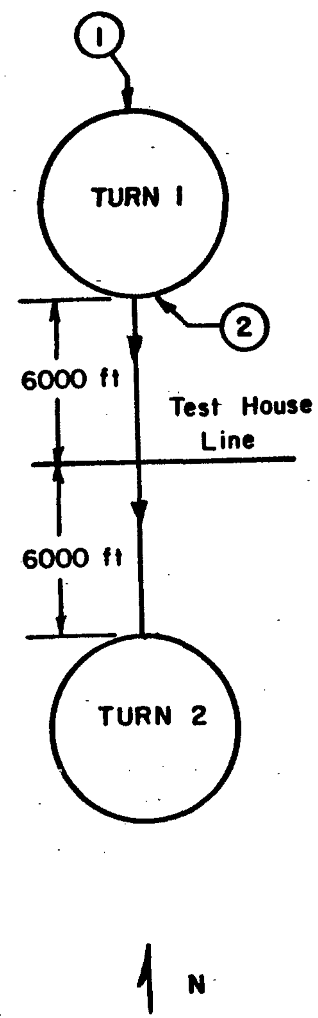
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   White -- 400 ft

   300 ft AGL



Run Number 22

Time ________

Heading 18

Red -- 2000 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

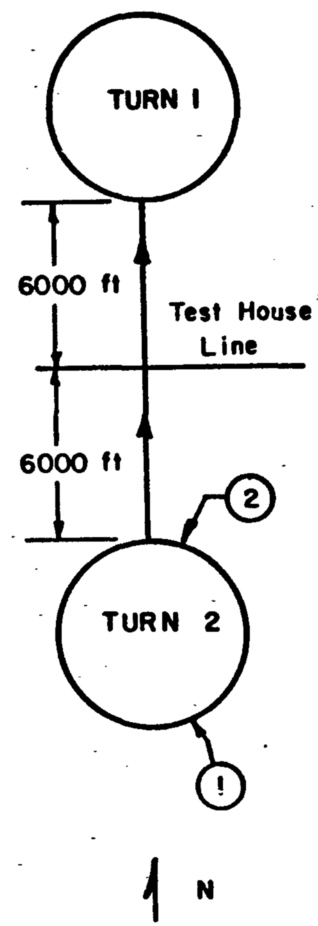
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Yellow -- 1000 ft

   300 ft AGL



Run Number 21

Time ________

Heading 36

Red -- 2000 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

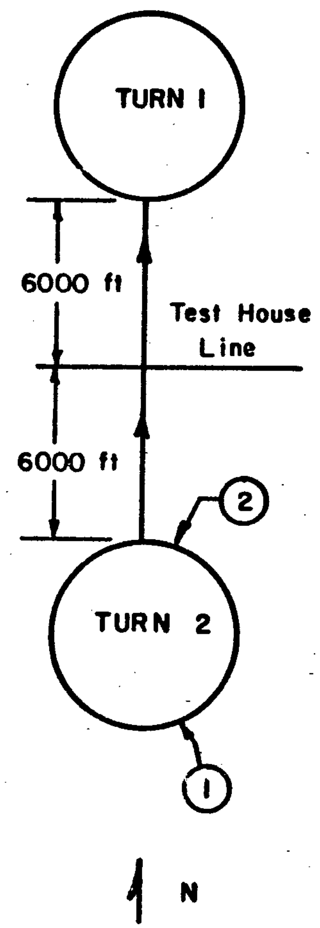
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Red -- 2000 ft

   300 ft AGL



Run Number 23

Time ______

Heading 36

Yellow -- 1000 ft

300 ft AGL

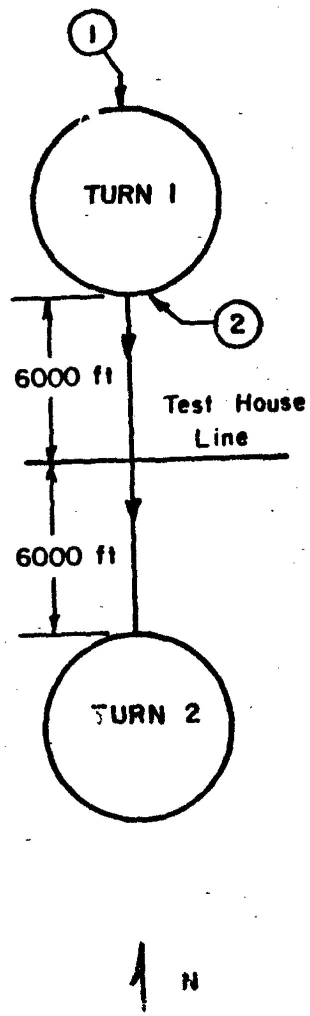
1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

2. Call when 6000 ft from Test House Line.

   Complete run.

3. Refuel and call in.



Run Number 24

Time ____________

Heading 18

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

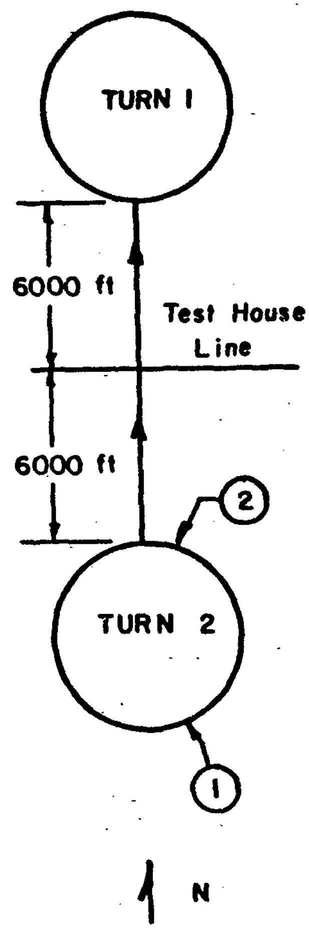
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

Heading 36

Orange -- 0 ft

200 ft AGL



Run Number 25

Time ____________

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

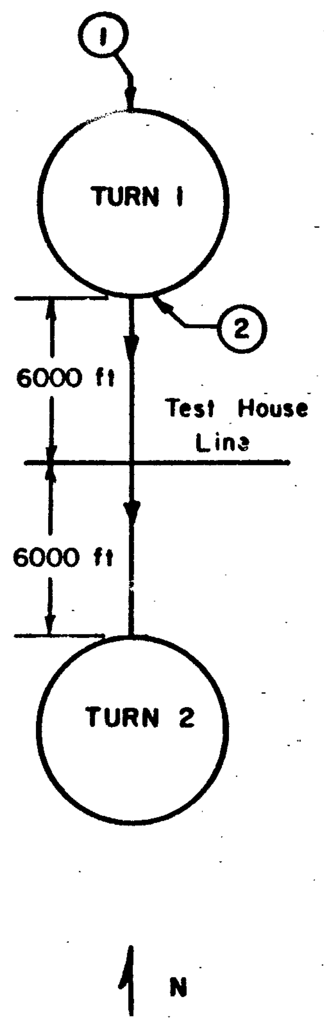
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

Heading 18

Yellow -- 1000 ft

300 ft AGL



Run Number 26

Time ______

Heading 18

Yellow-- 1000 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

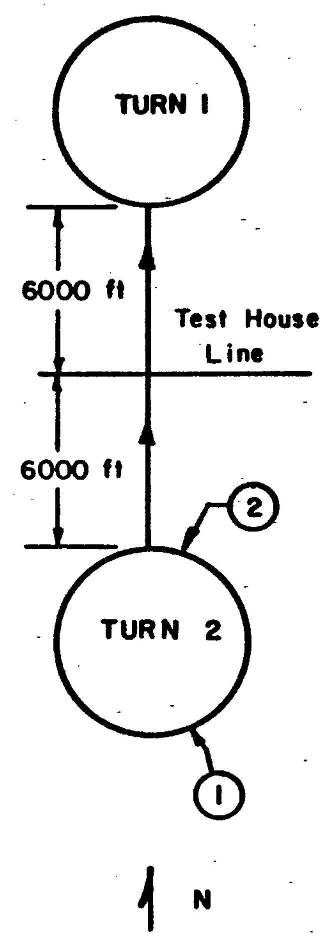
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

Heading 36

Yellow -- 1000 ft

300 ft AGL



Run Number 27

Time ______

Heading 36

Yellow -- 1000 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

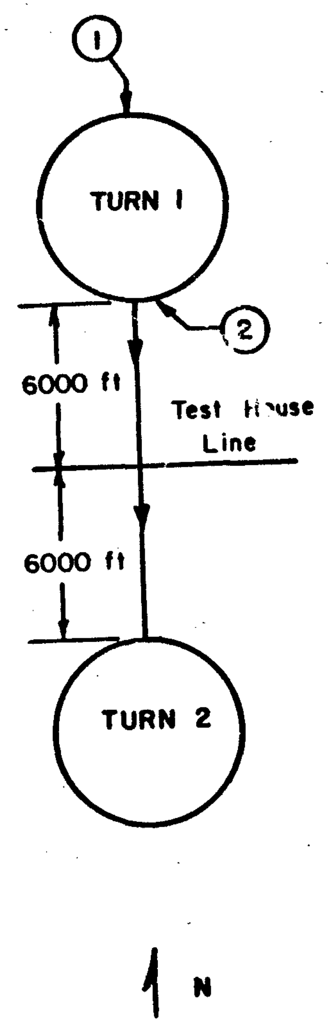
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

Heading 18

Orange -- 0 ft

200 ft AGL



Run Number 28

Time ____

Heading 18

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

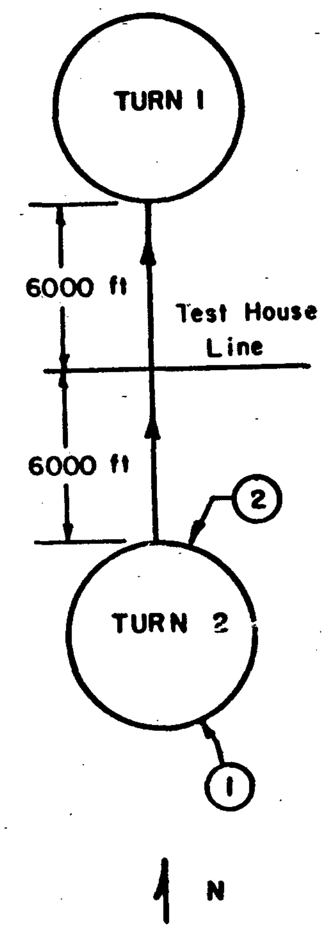
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Red -- 2000 ft

   300 ft AGL



Run Number 29

Time ____

Heading 36

Red -- 2000 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

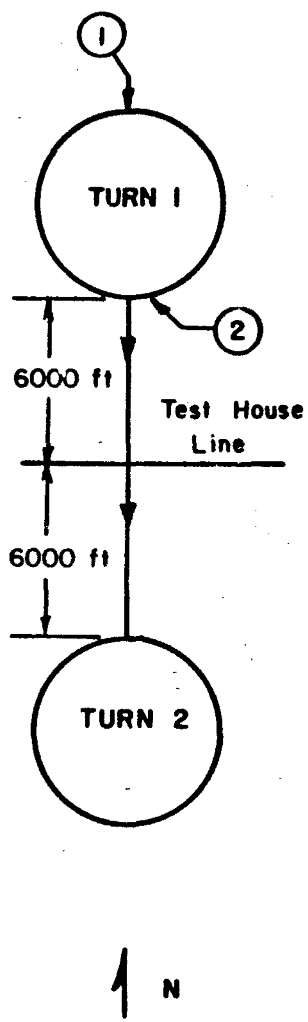
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Yellow -- 1000 ft

   200 ft AGL



Run Number 30

Time ____________

Heading 18

Yellow -- 1000 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

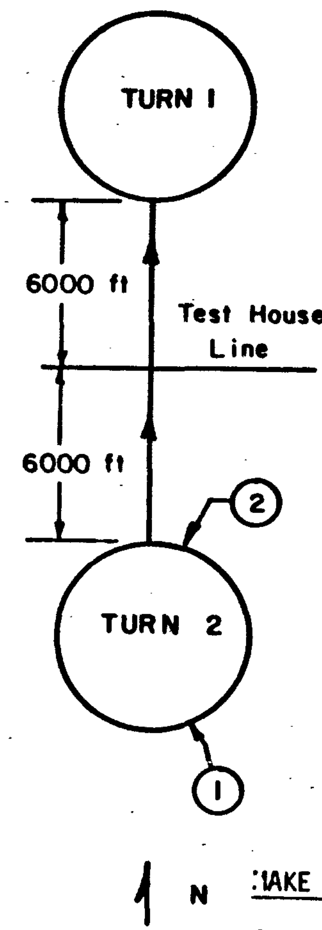
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

Heading 36

White -- 400 ft

300 ft AGL



Run Number 31

Time ____________

Heading 36

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

2. Call when 6000 ft from Test House Line.

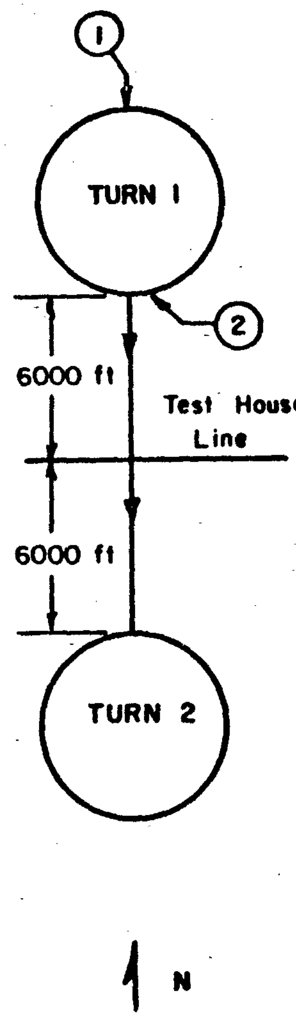
   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

Heading 18

Orange -- 0 ft

100 ft AGL

MAKE 1 EXTRA LOOP OF TURN 1 AND THE[illegible] RUN 32.



Run Number 32

Time ______

Heading 18

Orange-- 0 ft

100 ft AGL

1 Call when ½ through Turn 1.

Receive acknowledge to start run.

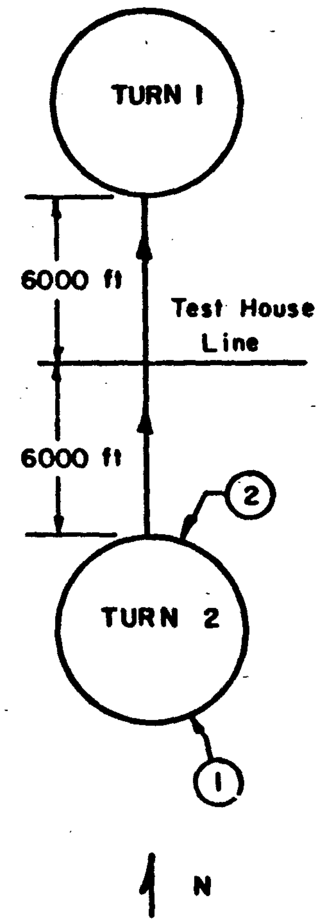
2. Call when 6000 ft from Test House Line.

Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

Heading 36

Orange -- 0 ft

200 ft AGL



Run Number 33

Time ______

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 2.

Receive acknowledge to start run.

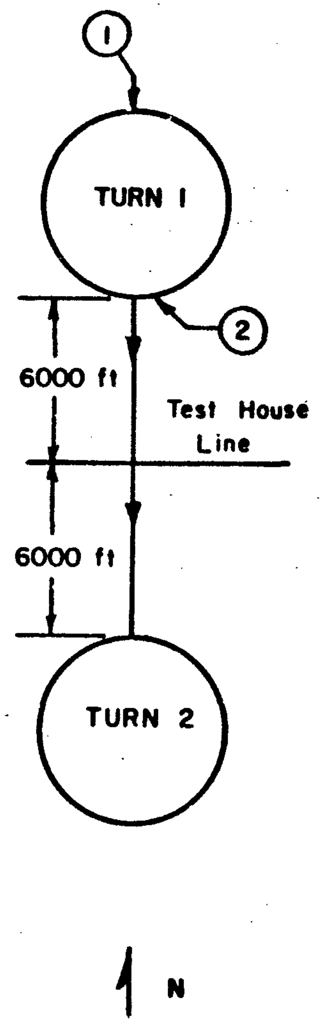
2. Call when 6000 ft from Test House Line.

Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

Heading 18

White -- 400 ft

300 ft AGL



Run Number 34

Time

Heading 18

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

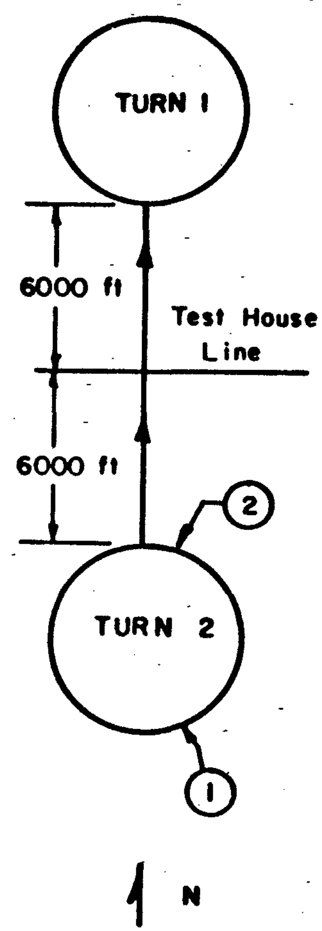
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Yellow -- 1000 ft

   300 ft AGL



Run Number 35

Time

Heading 36

Yellow -- 1000 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

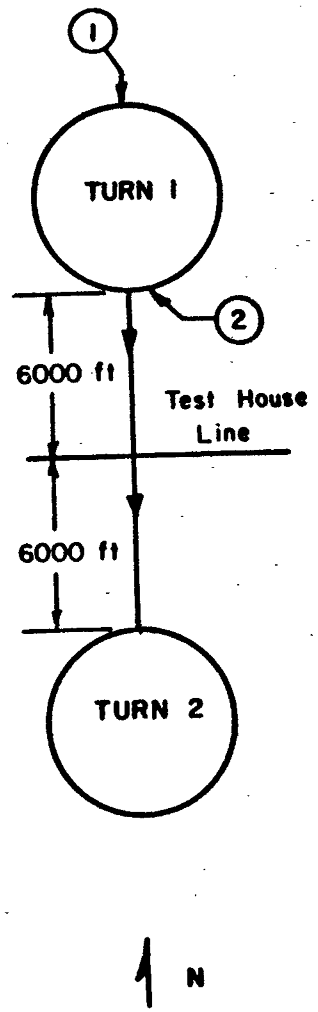
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Red -- 2000 ft

   300 ft AGL



Run Number 36

Time ______

Heading 18

Red -- 2000 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

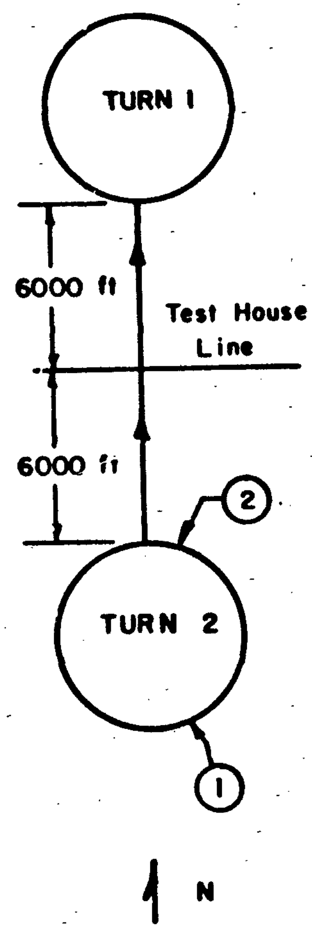
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   White -- 400 ft

   300 ft AGL



Run Number 37

Time ______

Heading 36

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

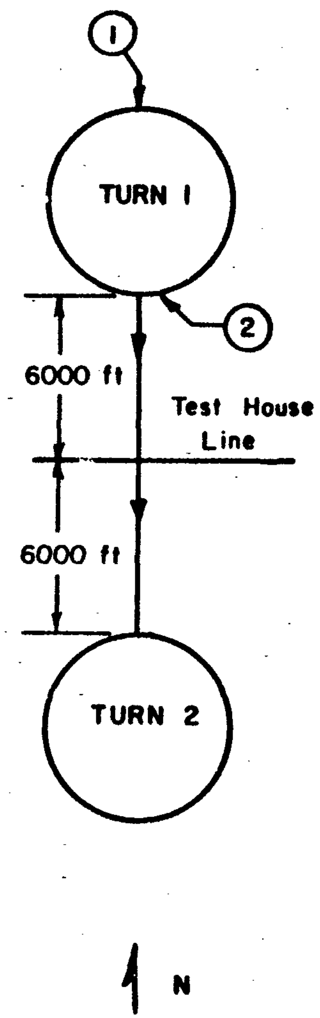
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Orange -- 0 ft

   200 ft AGL



Run Number 38

Time ________

Heading 18

Orange -- 0 ft

200 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

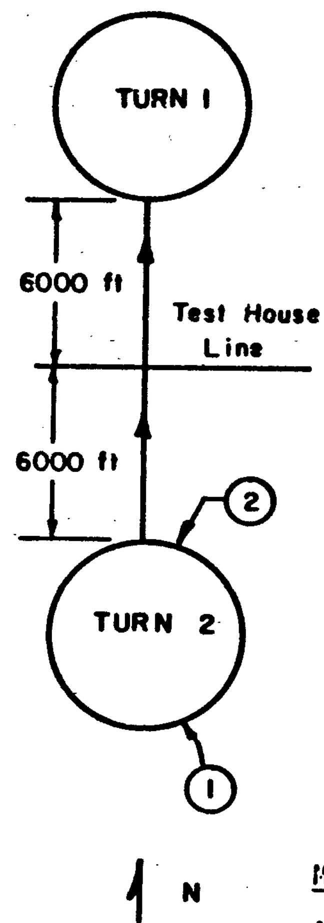
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Orange -- 0 ft

   100 ft AGL



Run Number 39

Time ________

Heading 36

Orange -- 0 ft

100 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

2. Call when 6000 ft from Test House Line.

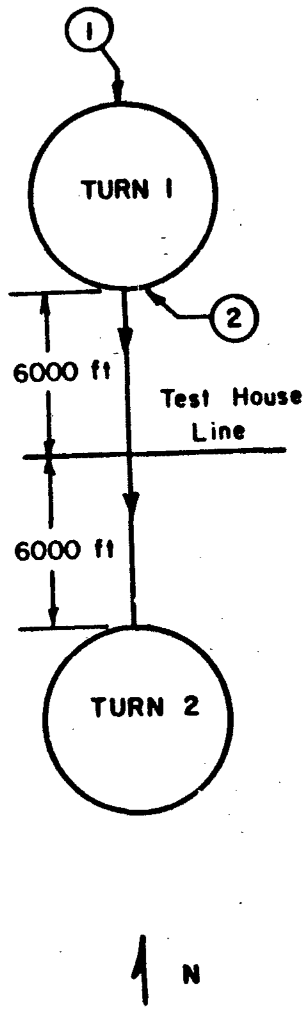
   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Orange -- 0 ft

   100 ft AGL

<u>MAKE 1 EXTRA LOOP OF TURN 1 AND THEN START RUN 40.</u>



Run Number 40

Time ______________

Heading 18

Orange -- 0 ft

100 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

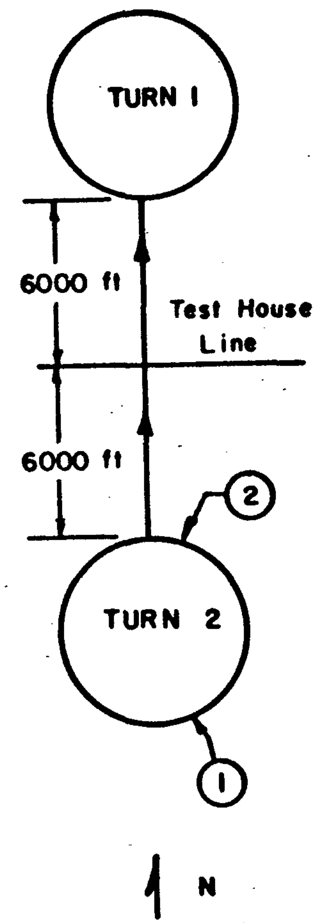
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Yellow -- 1000 ft

   300 ft AGL



Run Number 41

Time ______________

Heading 36

Yellow -- 1000 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

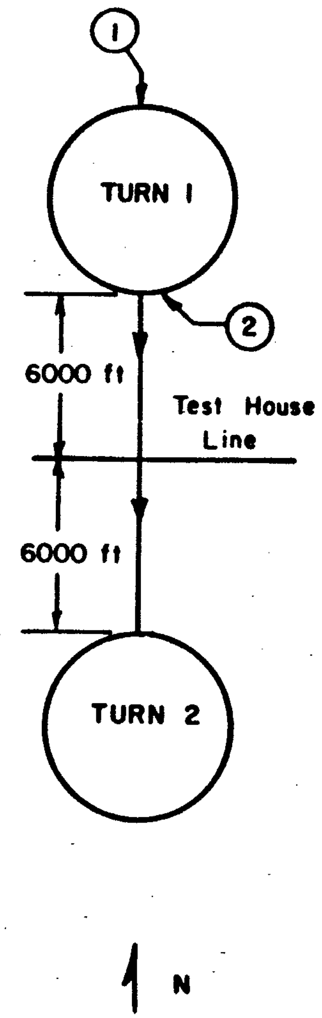
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   White -- 400 ft

   300 ft AGL



Run Number ___42___

Time ____________

Heading 18

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

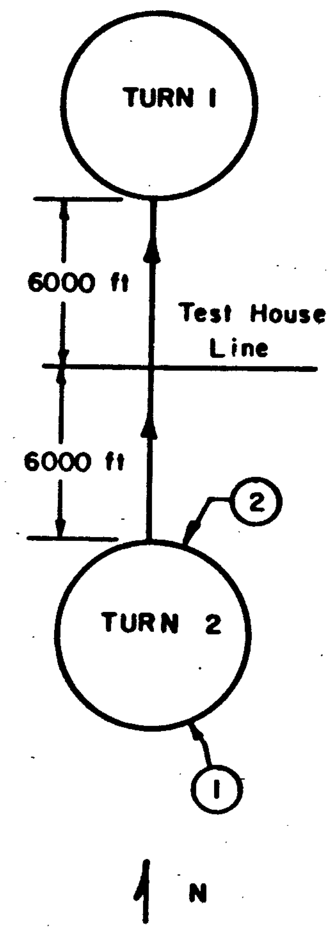
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   White -- 400 ft

   300 ft AGL



Run Number ___43___

Time ____________

Heading 36

White -- 400 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

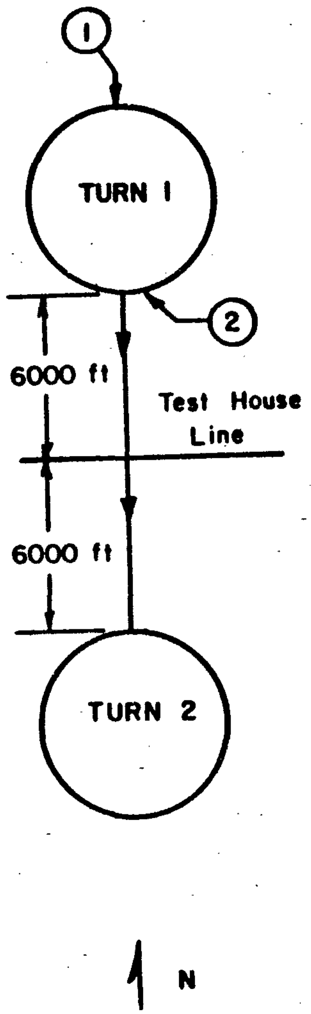
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Yellow -- 1000 ft

   300 ft AGL



Run Number 44

Time ____________

Heading 18

Yellow -- 1000 ft

300 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

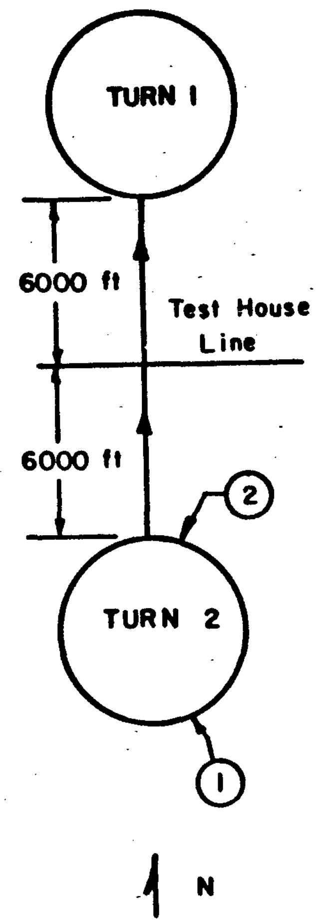
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

   Heading 36

   Red -- 2000 ft

   300 ft AGL



Run Number 45

Time ____________

Heading 36

Red -- 2000 ft

300 ft AGL

1. Call when ½ through Turn 2.

   Receive acknowledge to start run.

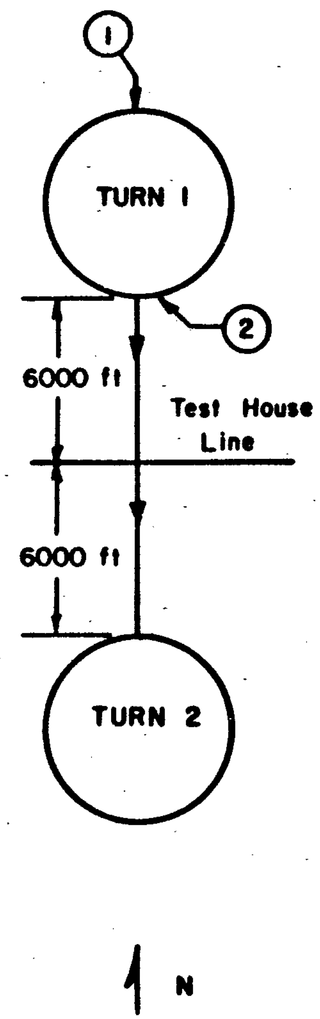
2. Call when 6000 ft from Test House Line.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

   Heading 18

   Orange -- 0 ft

   200 ft AGL



Run Number 46

Time ______

Heading 18

Orange- 0 ft

200 ft AGL

1. Call when ½ through Turn 1.

   Receive acknowledge to start run.

2. Call when 6000 ft from Test House Line.

   Complete run.

3. Test Complete. Return to field.

Helicopter Test

Construction Engineering Research Laboratory
Champaign, Illinois

October 1983

Pilot's Log

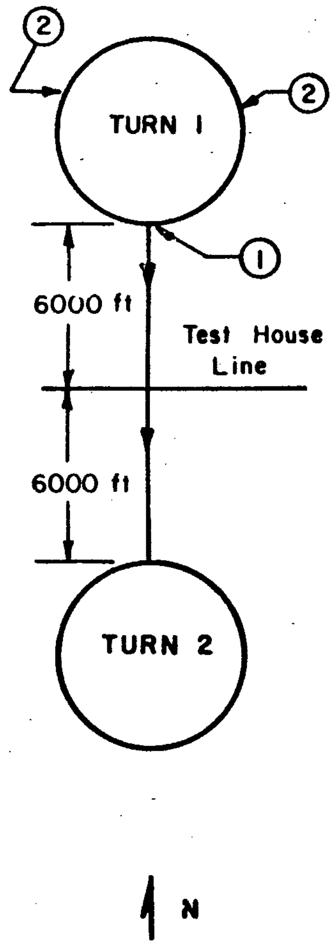
Monday, Tuesday, Thursday afternoons
Wednesday and Friday mornings

Pilot ______________________

Tail Number ________________

Date _______________________

Start Time _________________



Run Number 2

Time ____________

Heading 18

Red -- 2000 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

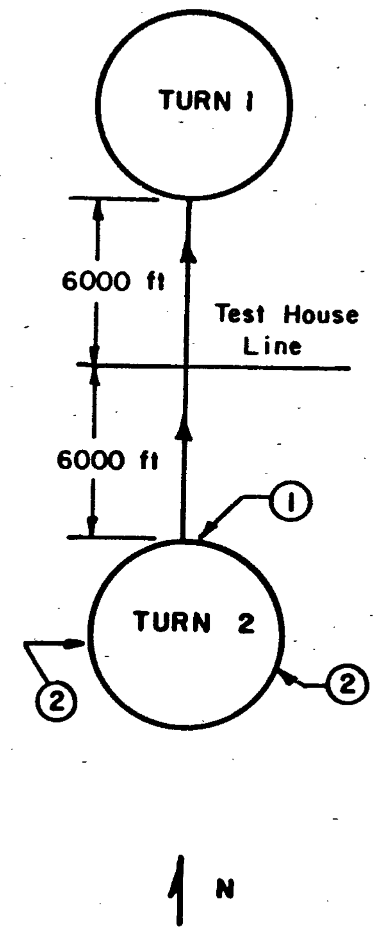
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R50 -27



Run Number 1

Time ____________

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

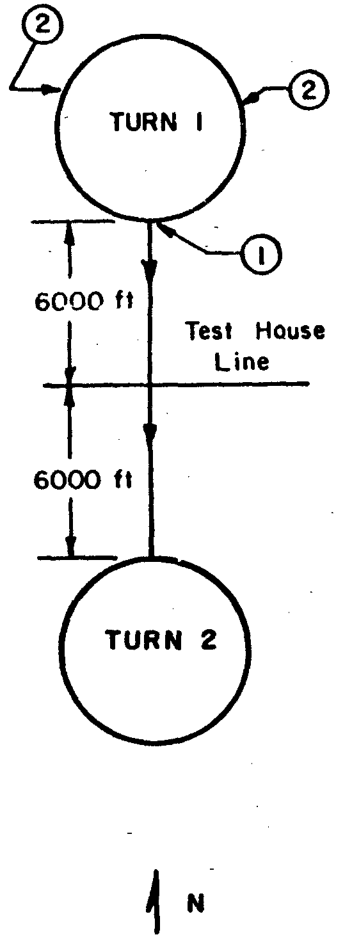
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R10 -15



Run Number 4

Time ______

Heading 18

Yellow -- 1000ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

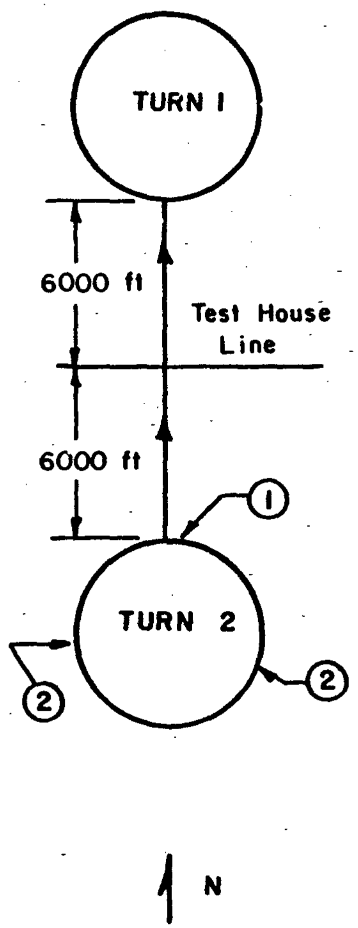
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R30 -23



Run Number 3

Time ______

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

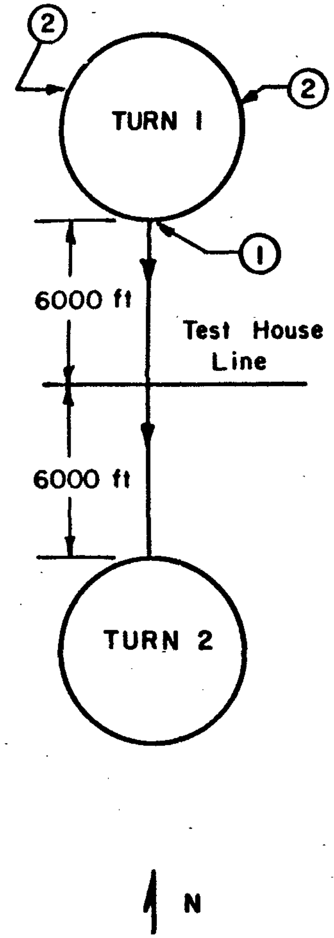
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R10 -19



Run Number 6

Time ______

Heading 18

Orange -- 0 ft

200 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

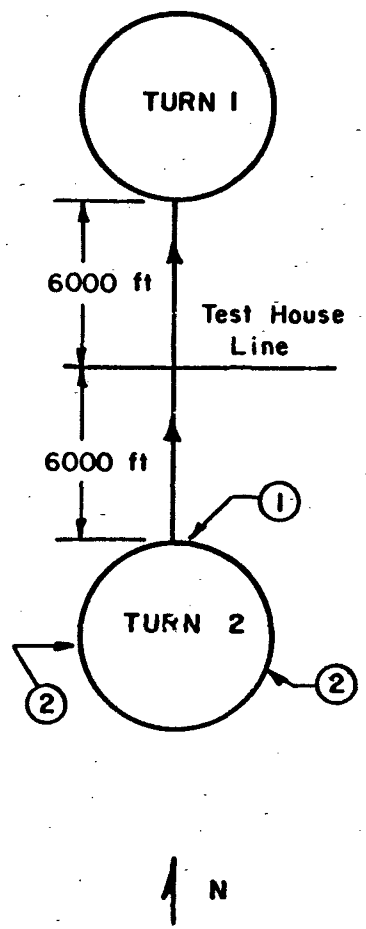
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R.0 -19



Run Number 5

Time ______

Heading 36

White -- 400 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

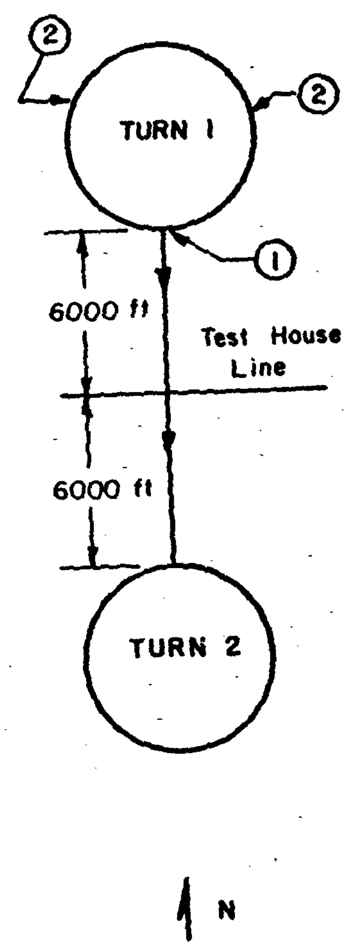
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R2(-19



Run Number 8

Time

Heading 18

Orange -- 0 ft

200 ft AGL

1. Call when starting Turn 1.

Choose direction of turn (RH or LH) to line up for this run.

Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

Complete run and enter Turn 2. Choose direction of turn (RH or LH) to line up for next run --

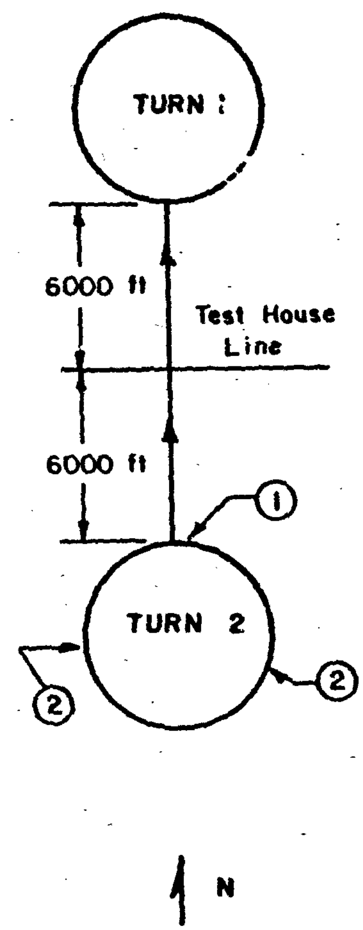
Heading 36

White -- 400 ft

300 ft AGL

COMPUTER FIRST

R10 -11



Run Number 7

Time

Heading 36

Orange-- 0 ft

100 ft AGL

1. Call when starting Turn 2.

Choose direction of turn (RH or LH) to line up for this run.

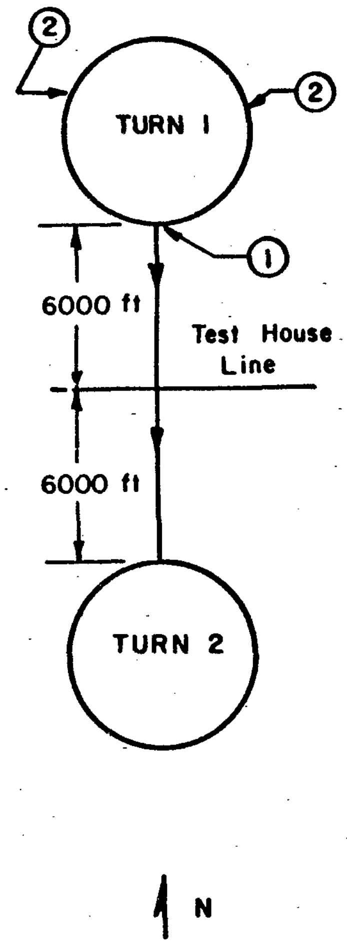
Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

Complete run and go on to next run.

COMPUTER FIRST

R05 -7



Run Number 10

Time ______

Heading 18

Yellow-- 1000 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

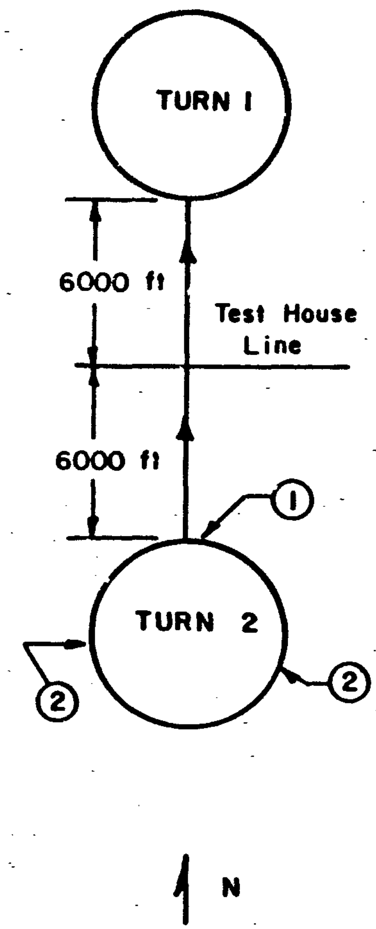
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R30-19



Run Number 9

Time ______

Heading 36

White -- 400 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

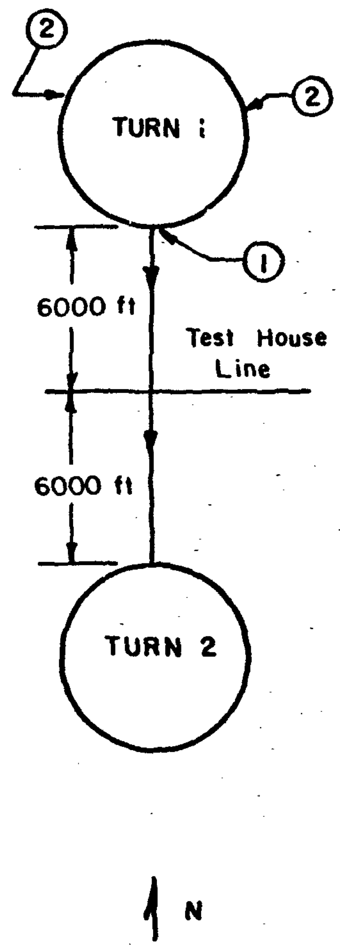
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R20-23



Run Number 12

Time ______

Heading 18

White -- 400ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

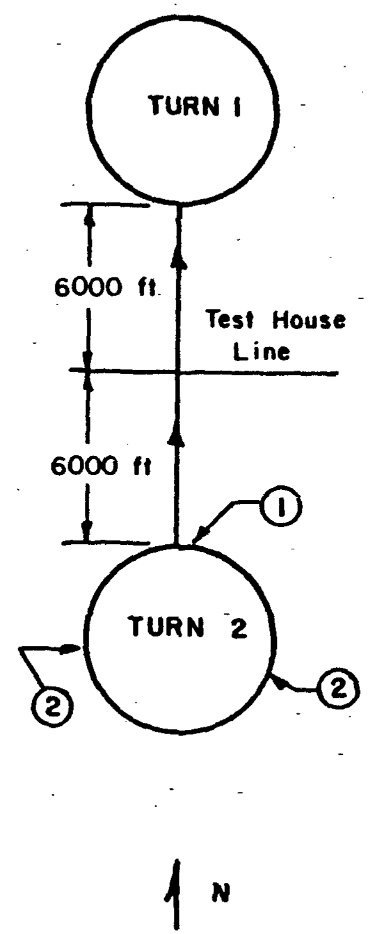
   Receive acknowledge to start run.

2. Call when ½ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R20 -19



Run Number 11

Time ______

Heading 36

Orange -- 0 ft

100 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

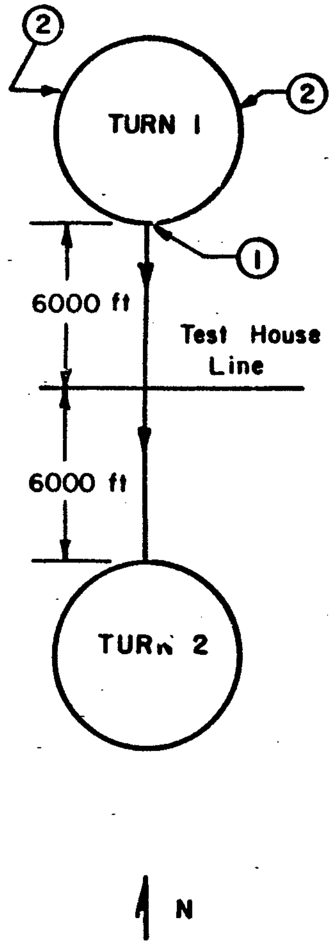
   Receive acknowledge to start run.

2. Call when ½ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R5 -3



Run Number 14

Time ____________

Heading 18

White -- 400ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

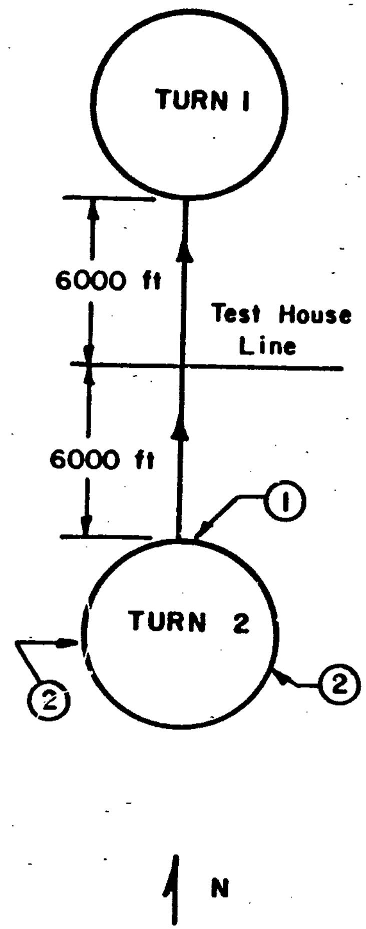
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

<u>COMPUTER FIRST</u>

R20 -23



Run Number 13

Time ____________

Heading 36

Yellow -- 1000 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

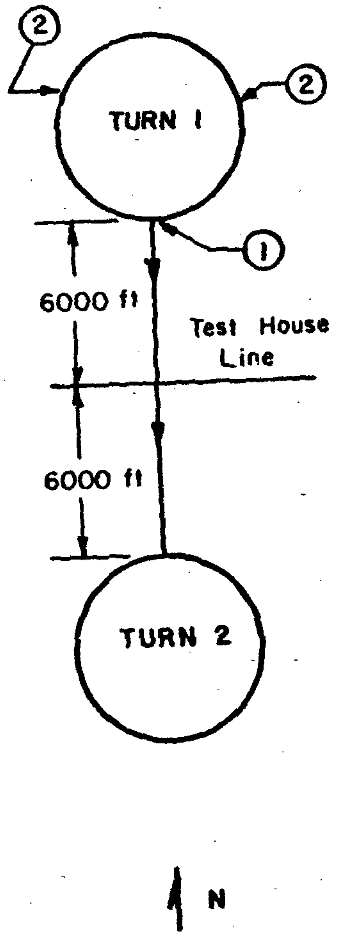
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

<u>COMPUTER FIRST</u>

R30 -27



Run Number 16

Time ______

Heading 18

Orange-- 0 ft

200 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and Enter turn 2. Choose direction of turn (RH or LH) to line up for next run --

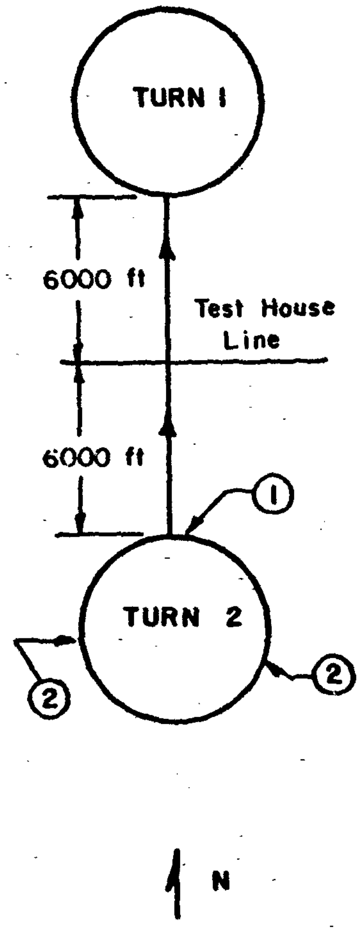
   Heading 36

   Orange -- 0 ft

   200 ft AGL

COMPUTER FIRST

R10-15



Run Number 15

Time ______

Heading 36

White-- 400 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to lin up for this run.

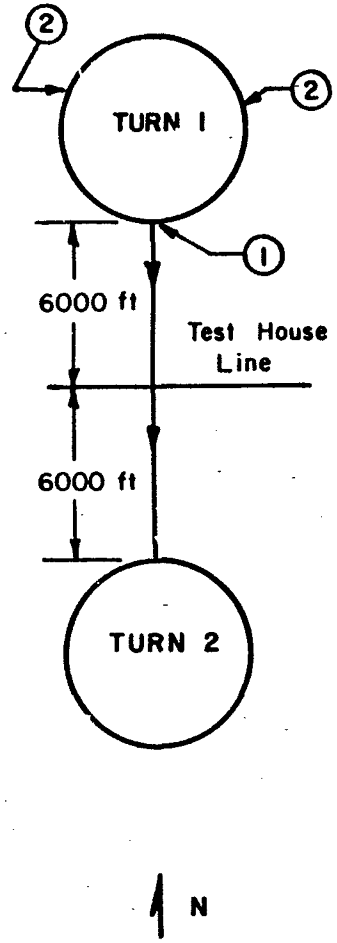
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R20-15



Run Number 18

Time ______________

Heading 18

Orange-- 0 ft

100 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

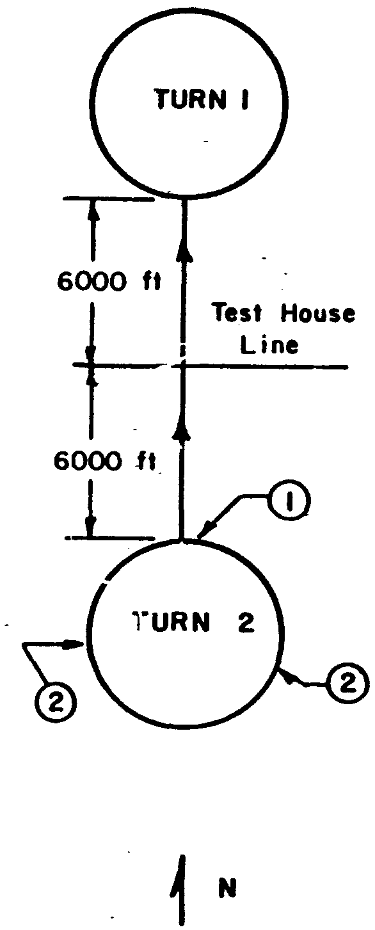
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R5 -7



Run Number 17

Time ______________

Heading 36

Orange -- 0 ft

200 ft [illegible]

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

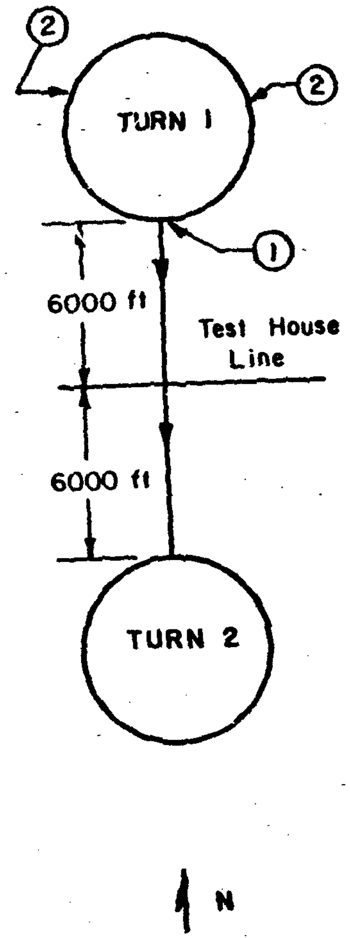
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R10 -11



Run Number 20

Time ______________

Heading 18

White -- 400 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

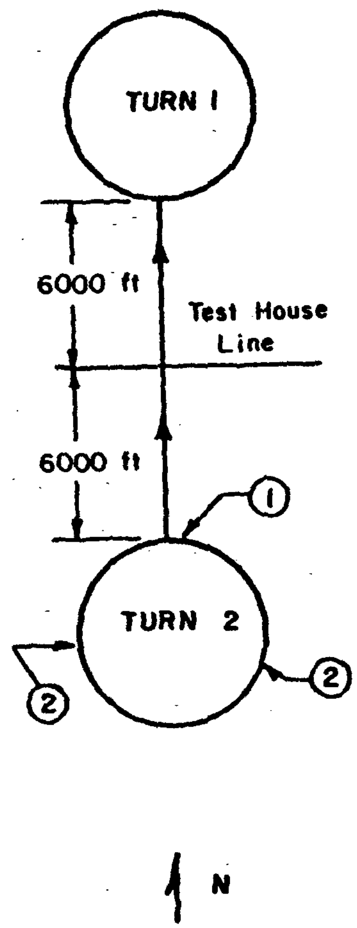
   Receive acknowledge to start run.

2. Call when ½ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R20 -15



Run Number 19

Time ______________

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

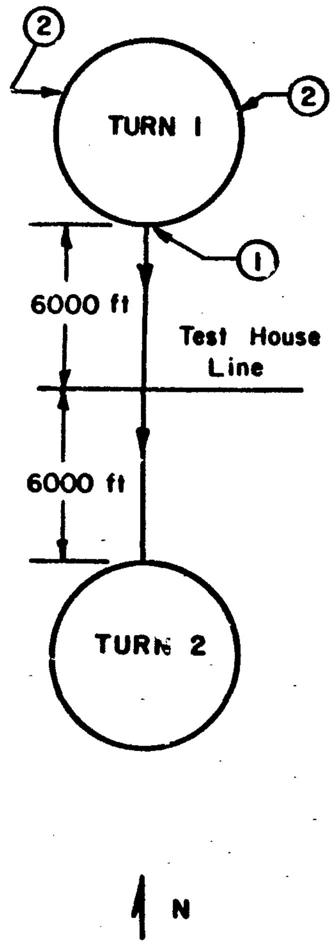
   Receive acknowledge to start run.

2. Call when ½ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R10 -19



Run Number 22

Time ____________

Heading 18

Red-- 2000 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

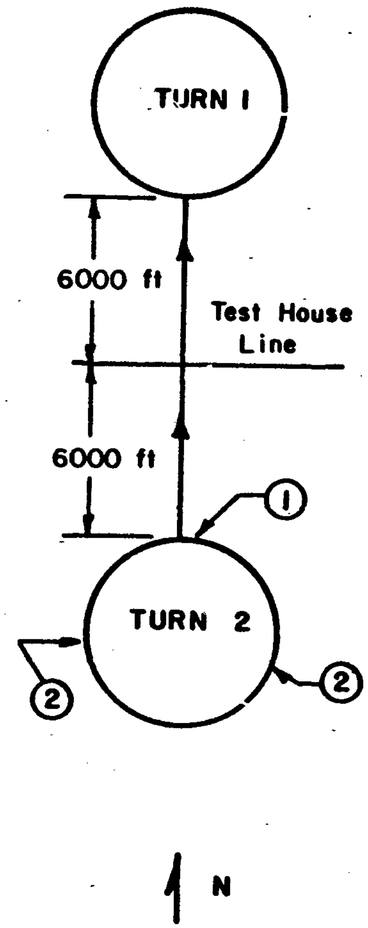
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R50-31



Run Number 21

Time ____________

Heading 36

Red -- 2000 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

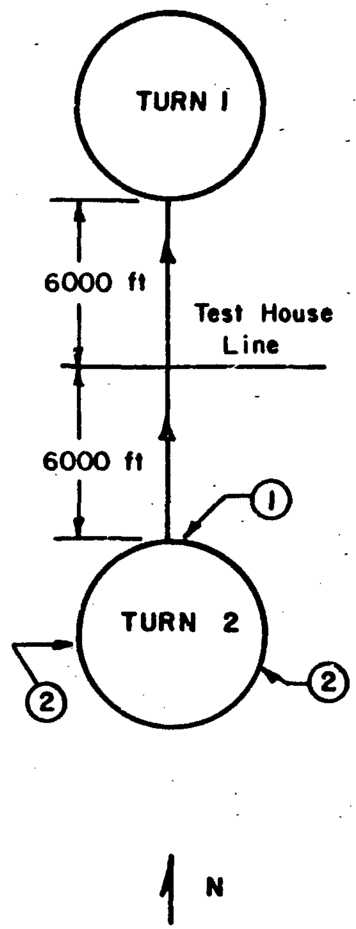
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R50-27



Run Number 23

Time ______

Heading 36

Yellow -- 1000 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

   Receive acknowledge to start run.

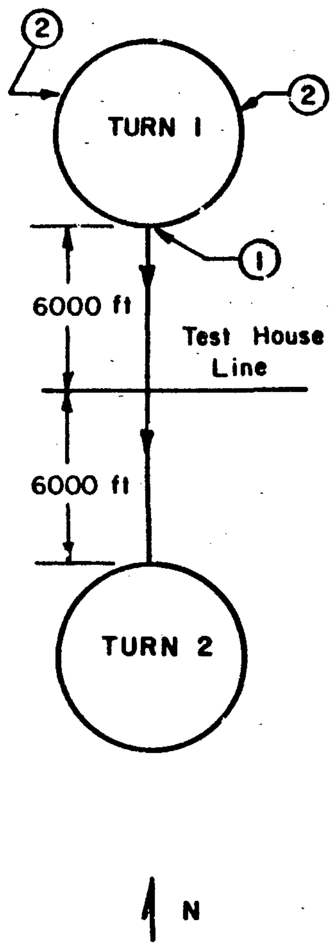
2. Call when ¼ through Turn 2.

   Complete run.

3. Refuel and call in.

COMPUTER FIRST

R30-23



Run Number 24

Time ________

Heading 18

White-- 400 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

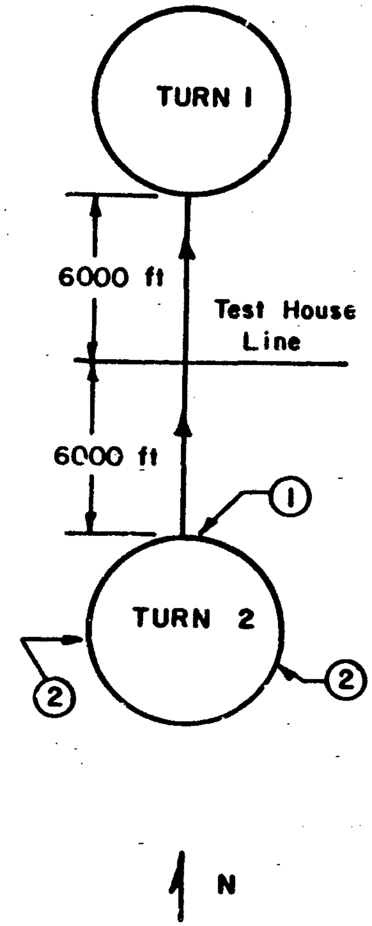
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

<u>COMPUTER FIRST</u>

R20-23



Run Number 25

Time ________

Heading 36

Orange-- 0 ft

200 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

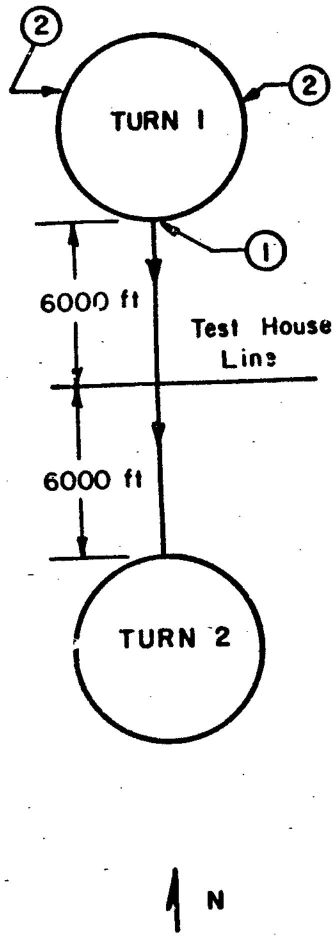
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

<u>COMPUTER FIRST</u>

R10-15



Run Number 26

Time ______

Heading 18

Yellow-- 1000 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

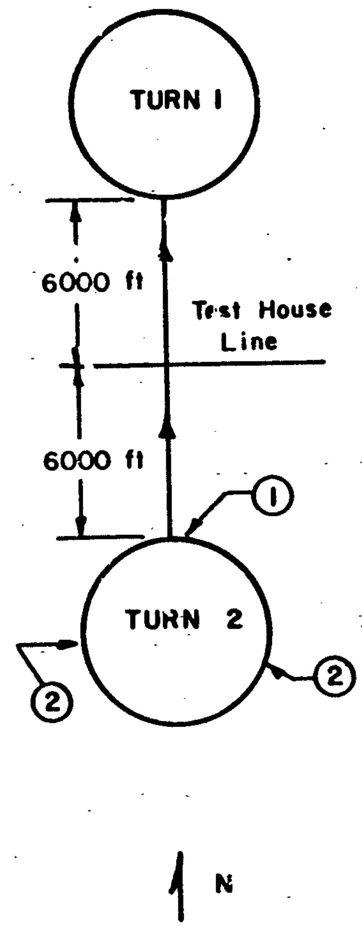
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

<u>COMPUTER FIRST</u>

R30-27



Run Number 27

Time ______

Heading 36

Yellow-- 1000 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

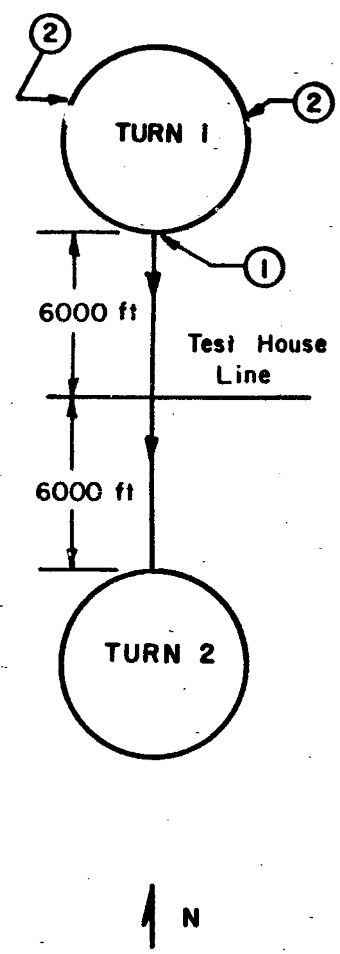
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

<u>COMPUTER FIRST</u>

R30-23



Run Number 28

Time ____________

Heading 18

Orange -- 0 ft

200 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

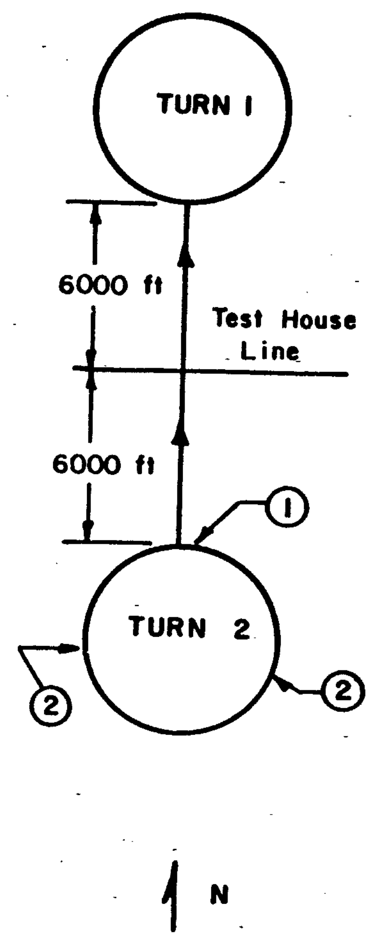
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R10 -11



Run Number 29

Time ____________

Heading 36

Red -- 2000 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

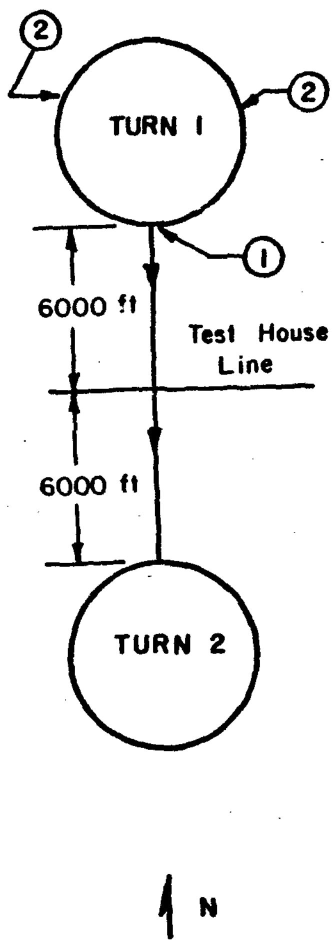
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R50 -23



Run Number 30

Time ______

Heading 18

Yellow-- 1000 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

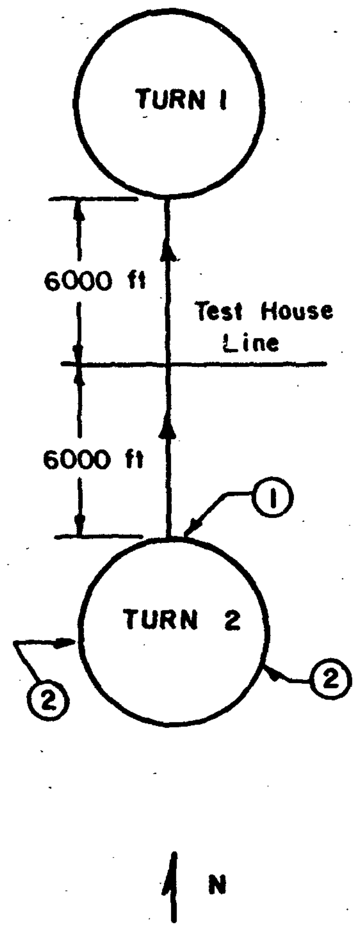
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R30 -19



Run Number 31

Time ______

Heading 36

White-- 400 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

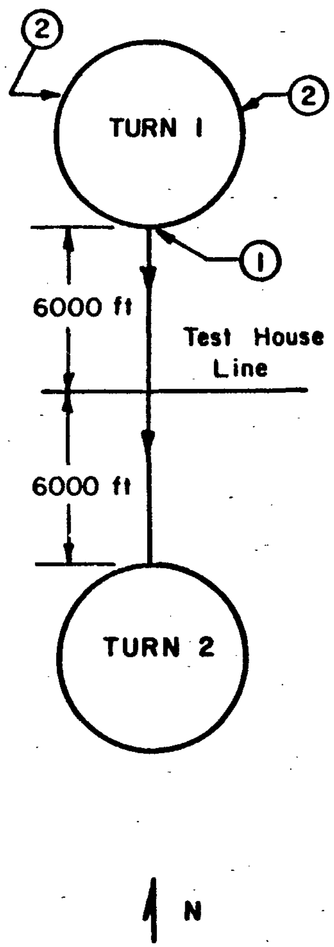
   Heading 18

   Orange -- 0 ft

   100 ft AGL

COMPUTER FIRST

R20 -19



Run Number 32

Time ______

Heading 18

Orange-- 0 ft

100 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

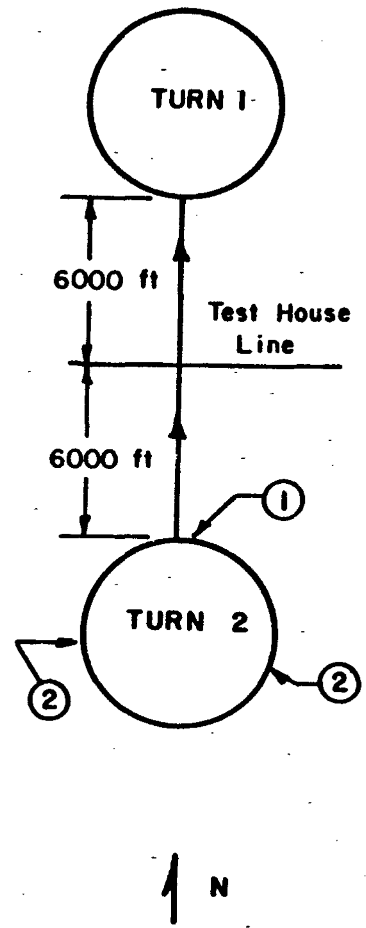
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R5-11



Run Number 33

Time ______

Heading 36

Orange -- 0 ft

200 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

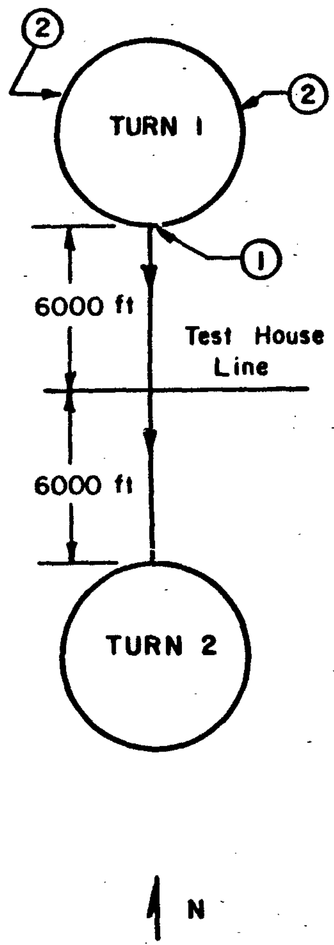
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R10-11



Run Number 34

Time ______

Heading 18

White-- 400 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

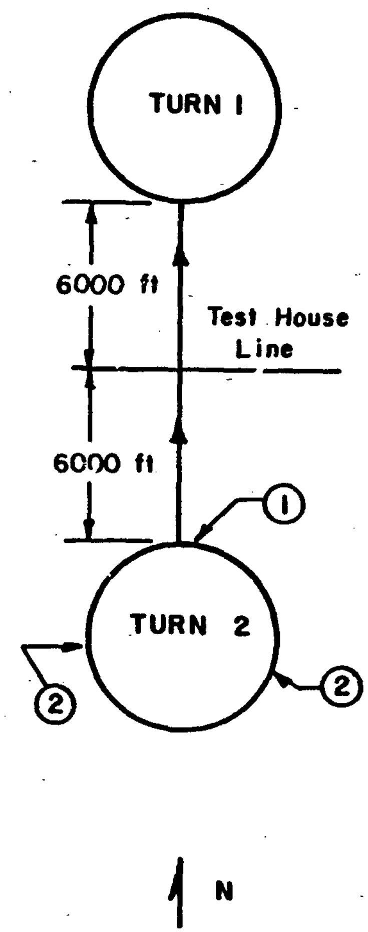
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R20 -19



Run Number 35

Time ______

Heading 36

Yellow--1000 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

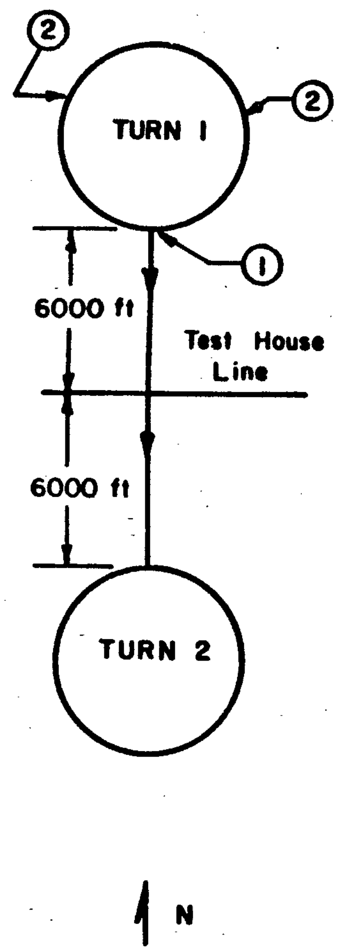
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R30 -19



Run Number 36

Time ____________

Heading 18

Red -- 2000 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

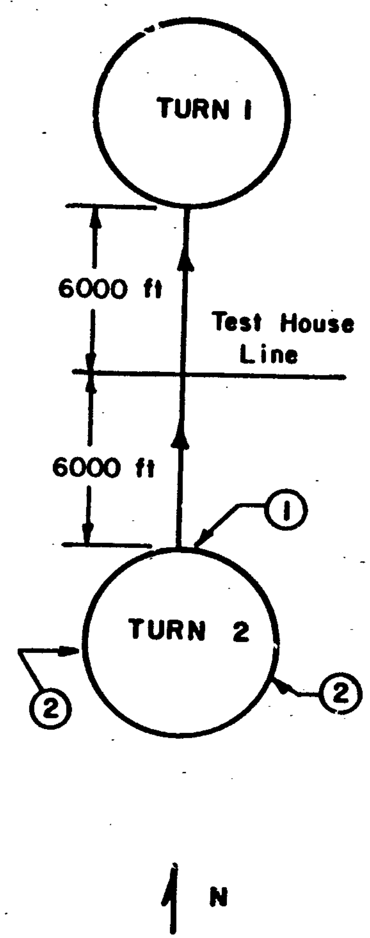
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R50 -23



Run Number 37

Time ____________

Heading 36

White- 400 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

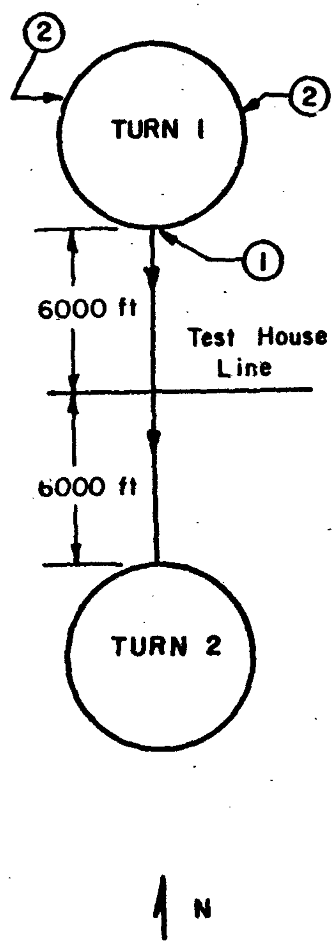
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R20 -15



Run Number 38

Time ________

Heading 18

Orange-- 0 ft

200 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

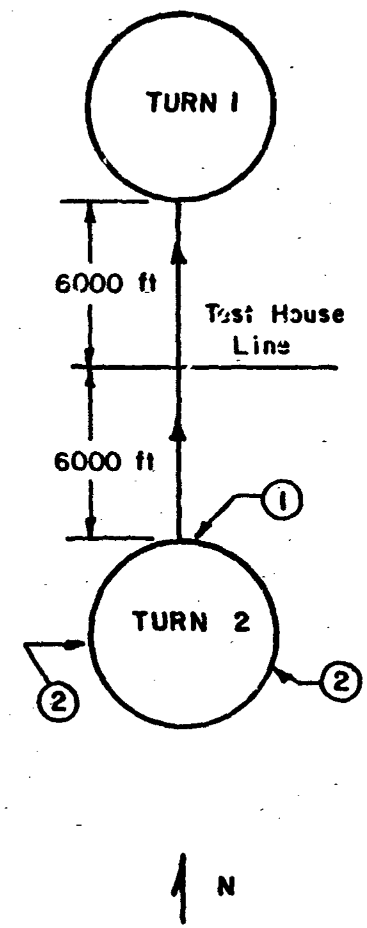
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R10 -15



Run Number 39

Time ________

Heading 36

Orange -- 0 ft

100 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and enter Turn 1. Choose direction of turn (RH or LH) to line up for next run --

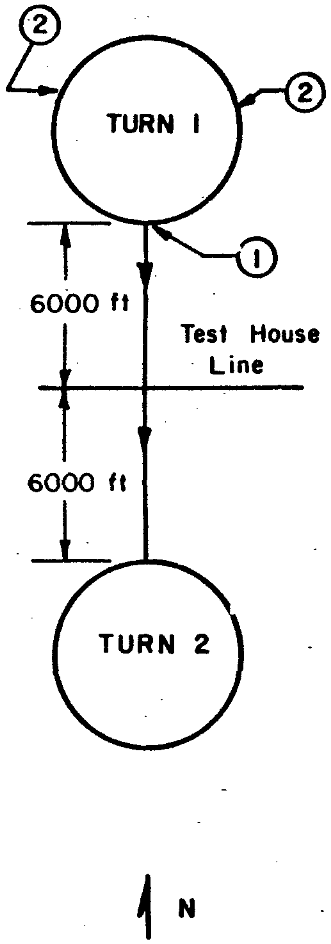
   Heading 18

   Orange -- 0 ft

   100 ft AGL

COMPUTER FIRST

R5-11



Run Number 40

Time ______

Heading 18

Orange-- 0 ft

100 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

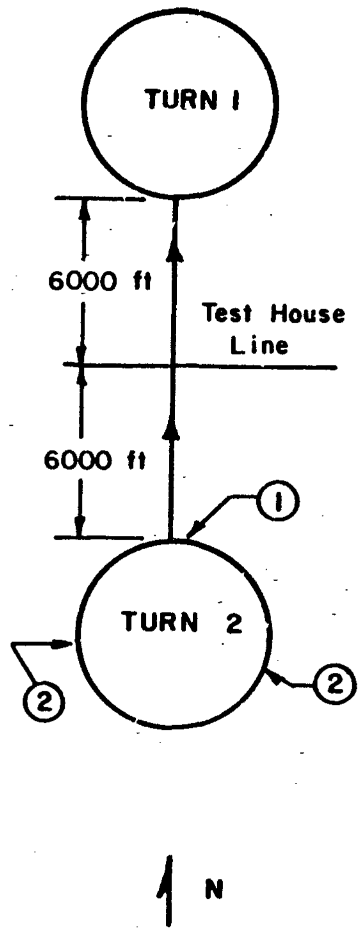
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R5-3



Run Number 41

Time ______

Heading 36

Yellow--1000 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

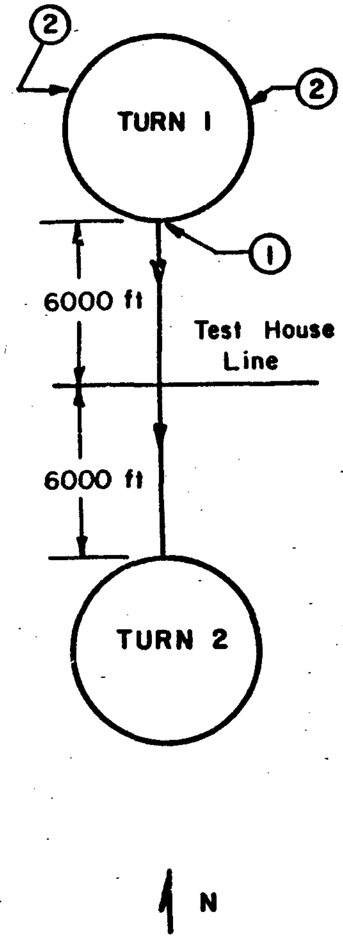
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R30-19



Run Number 42

Time ______

Heading 18

White-- 400 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

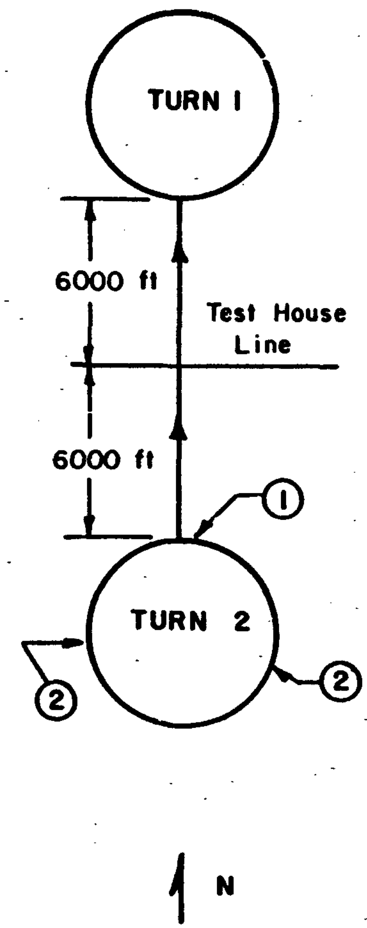
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

<u>COMPUTER FIRST</u>

R20 -15



Run Number 43

Time ______

Heading 36

White -- 400 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

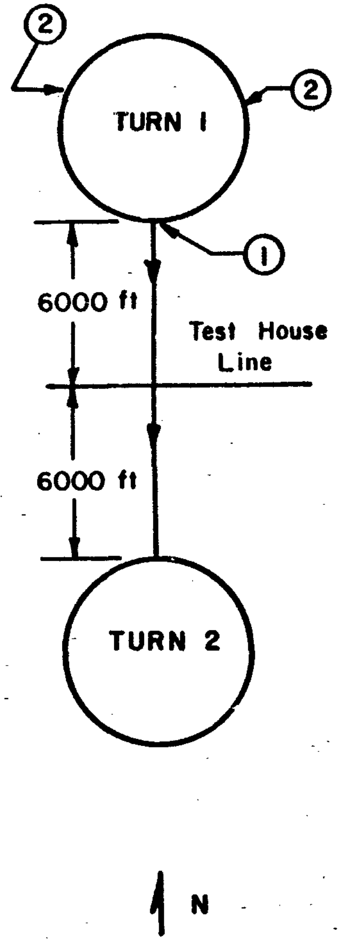
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

<u>COMPUTER FIRST</u>

R20 -23



Run Number 44

Time ______

Heading 18

Yellow-- 1000 ft

300 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

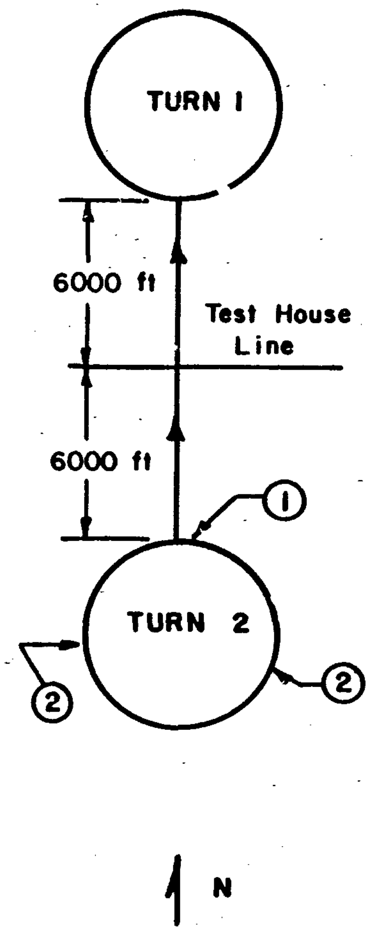
   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run and go on to next run.

COMPUTER FIRST

R30 -23



Run Number 45

Time ______

Heading 36

Red -- 2000 ft

300 ft AGL

1. Call when starting Turn 2.

   Choose direction of turn (RH or LH) to line up for this run.

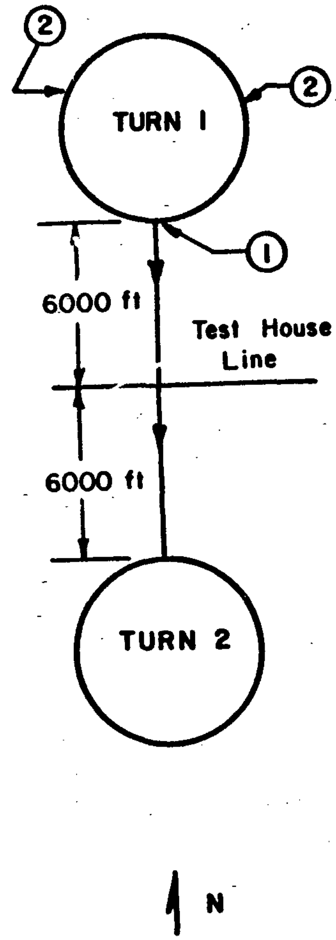
   Receive acknowledge to start run.

2. Call when ¼ through Turn 2.

   Complete run and go on to next run.

COMPUTER FIRST

R50-31



Run Number 46

Time ______

Heading 18

Orange -- 0 ft

200 ft AGL

1. Call when starting Turn 1.

   Choose direction of turn (RH or LH) to line up for this run.

   Receive acknowledge to start run.

2. Call when ¼ through Turn 1.

   Complete run.

3. Test complete. Return to field.

<u>COMPUTER FIRST</u>

R10-19

APPENDIX C:

BASIC DATA REDUCTION

Figures C1 through C20 contain the subject response results by A-weighted helicopter SEL for various 4-dB-wide control SELs. The data are the indoors only and are split by location and subjective level of vibration or rattle as reported by the USA-CERL researcher. Regression lines (solid) are fit to the data when three or more data points exist.

Data for which the number of subjects is less than 1.5 times the average difficulty number (subjects reported difficulty in deciding on a 5-point scale--see Appendix A) are circled. When it appears that the resulting new regression line will be significantly different from the original then an approximate new regression line (dashed) is fit to the data sets that have one or more circled points, provided at least three uncircled data points remain.

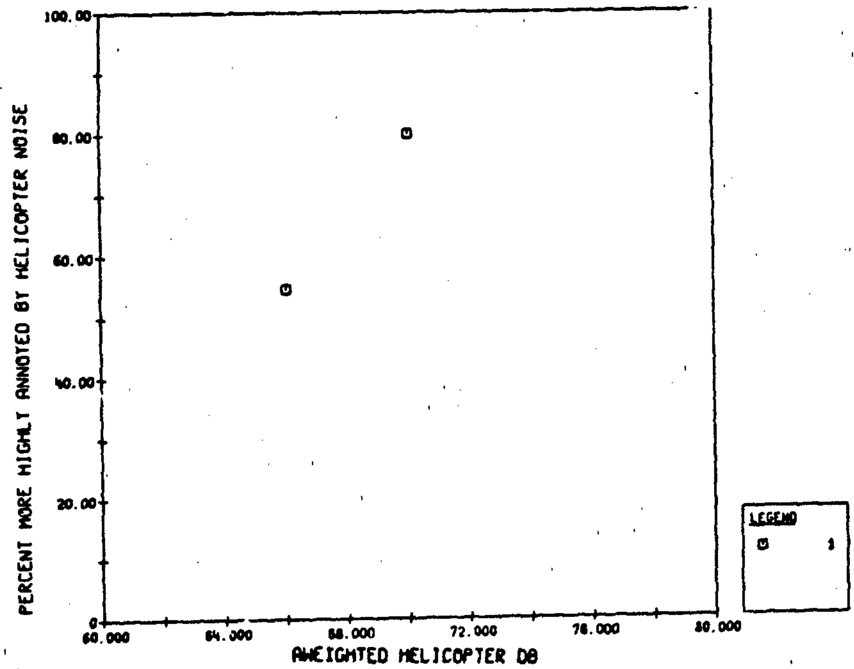


Figure C1. A-weighted mobile home; white noise 60 to 64 dB.

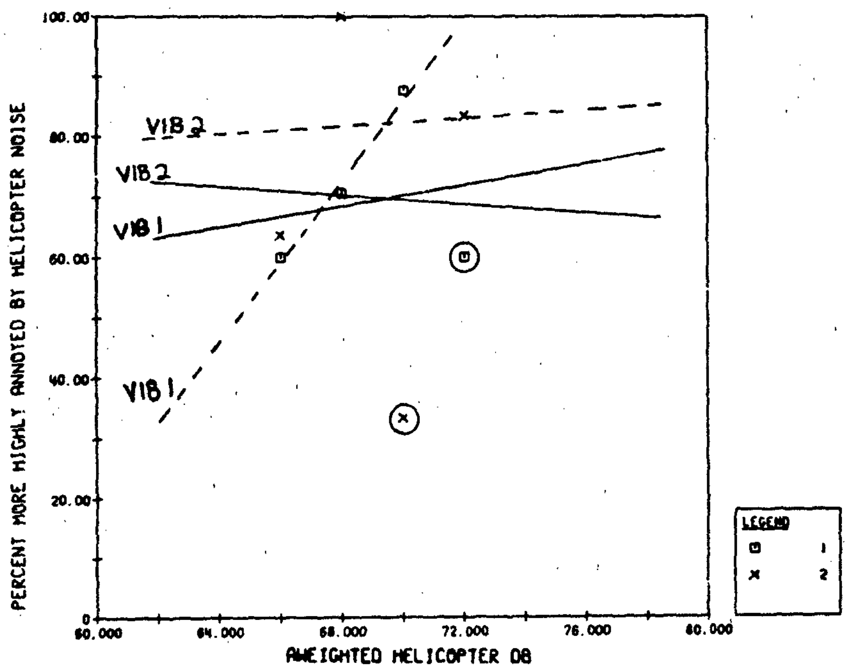


Figure C2. A-weighted mobile home; white noise 64 to 68 dB.

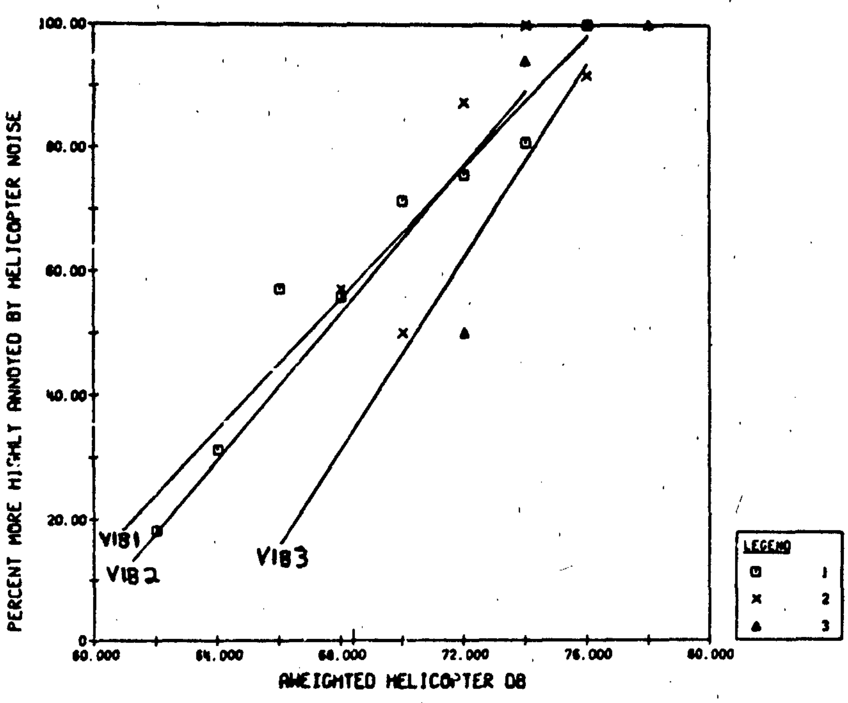


Figure C3. A-weighted mobile home; white noise 68 to 72 dB.

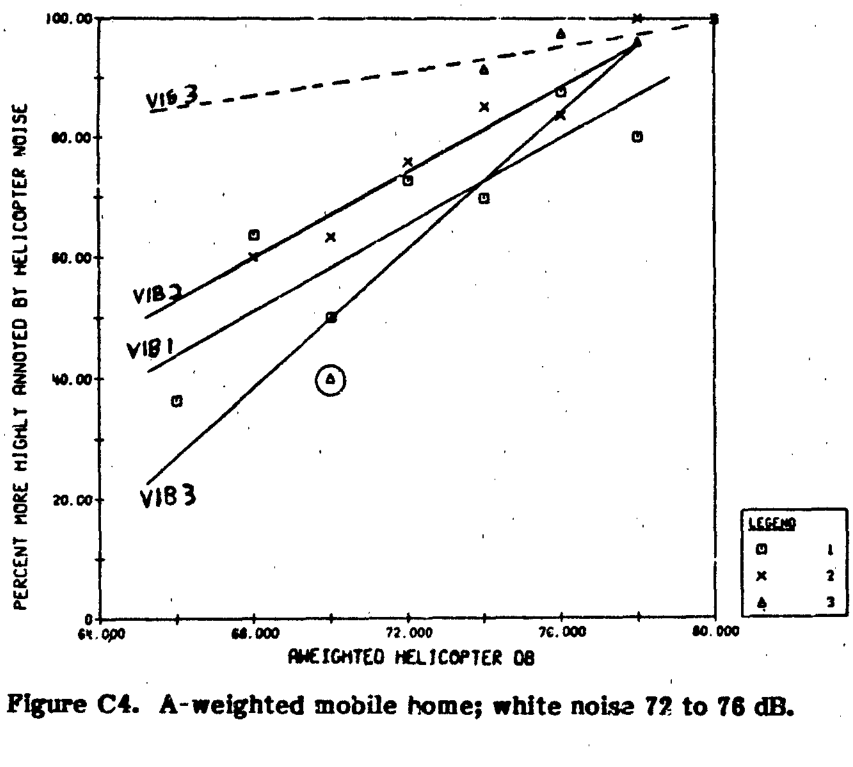


Figure C4. A-weighted mobile home; white noise 72 to 76 dB.

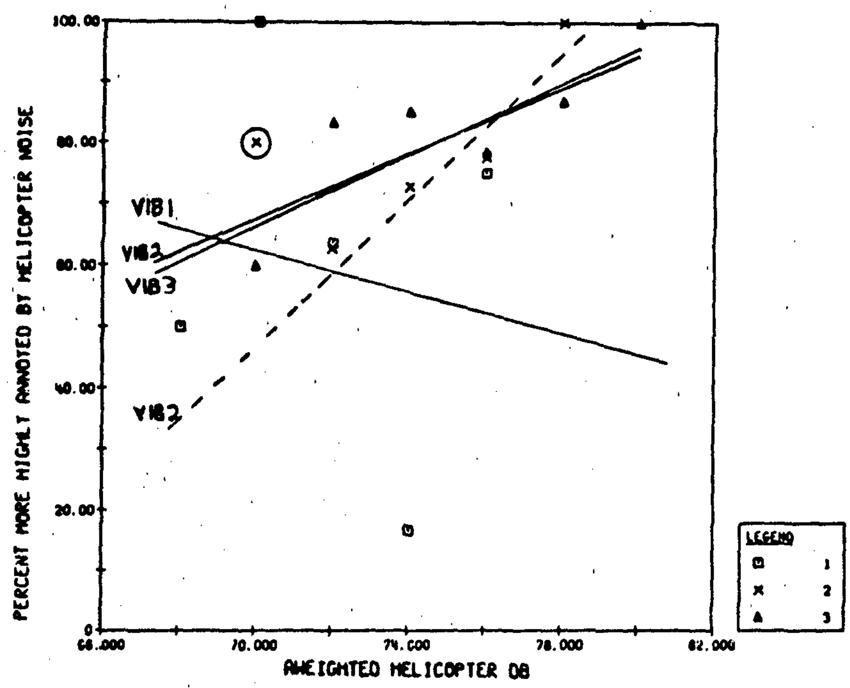


Figure C5. A-weighted mobile home; white noise 76 to 80 dB.

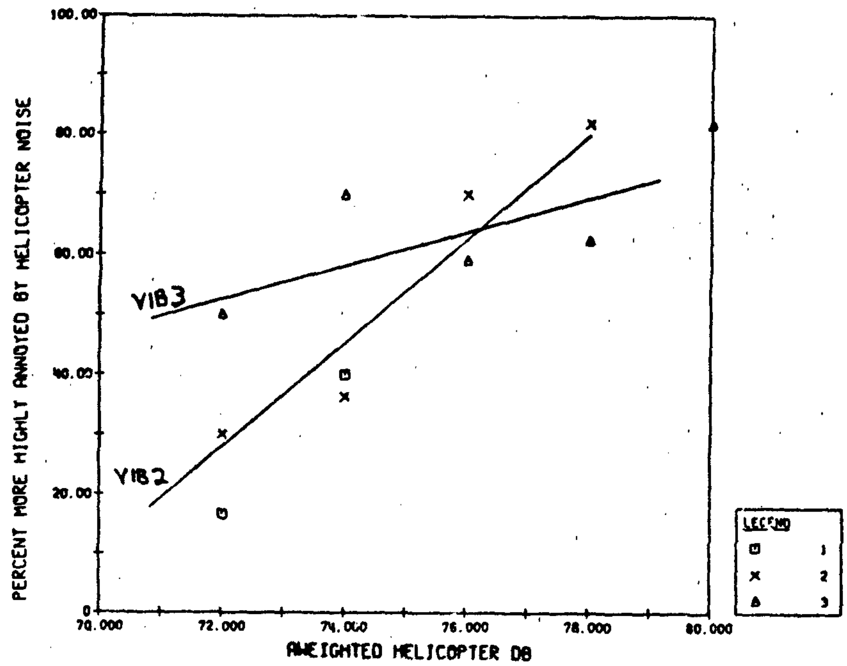


Figure C6. A-weighted mobile home; white noise 80 to 84 dB.

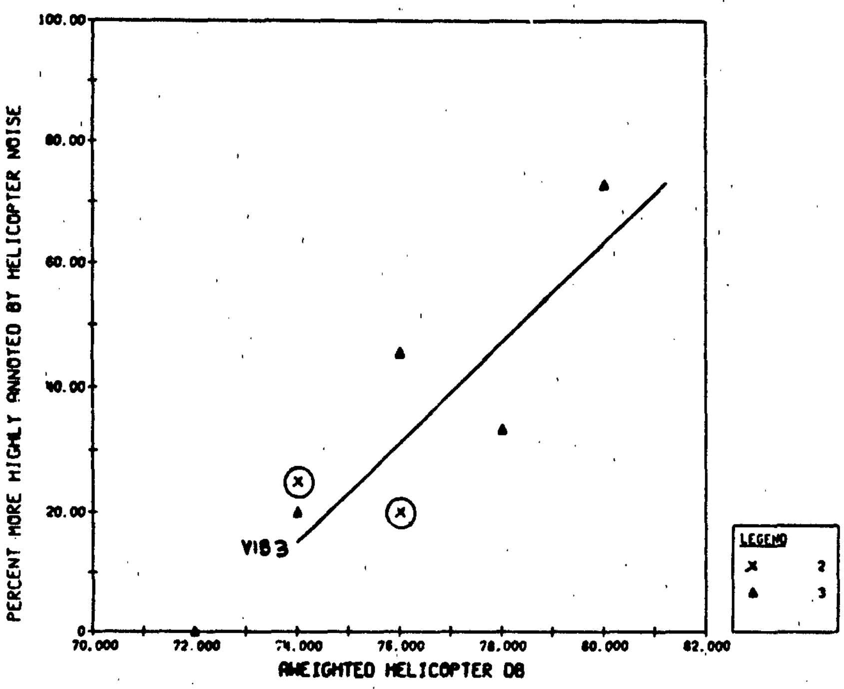


Figure C7. A-weighted mobile home; white noise 84 to 88 dB.

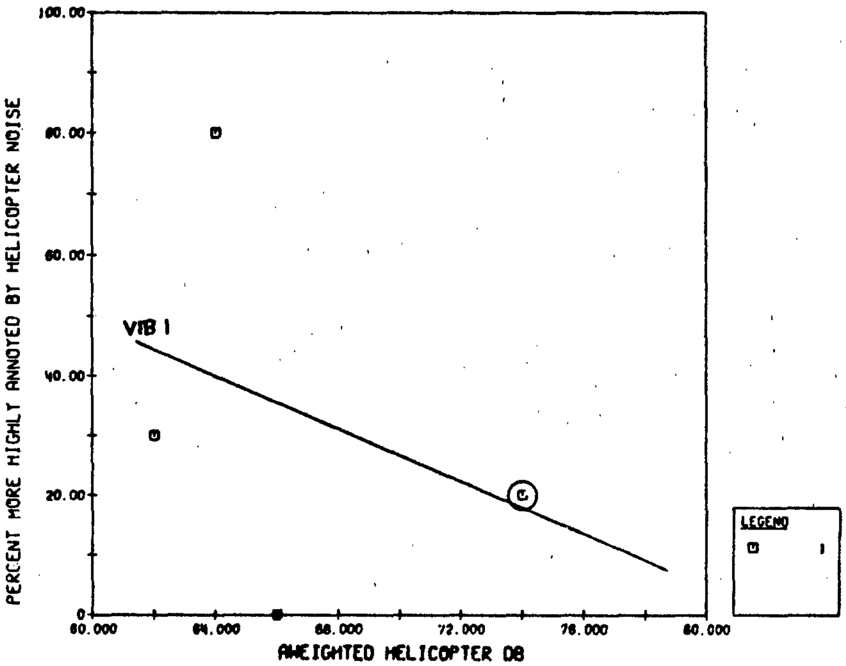


Figure C8. A-weighted living room; white noise 60 to 64 dB.

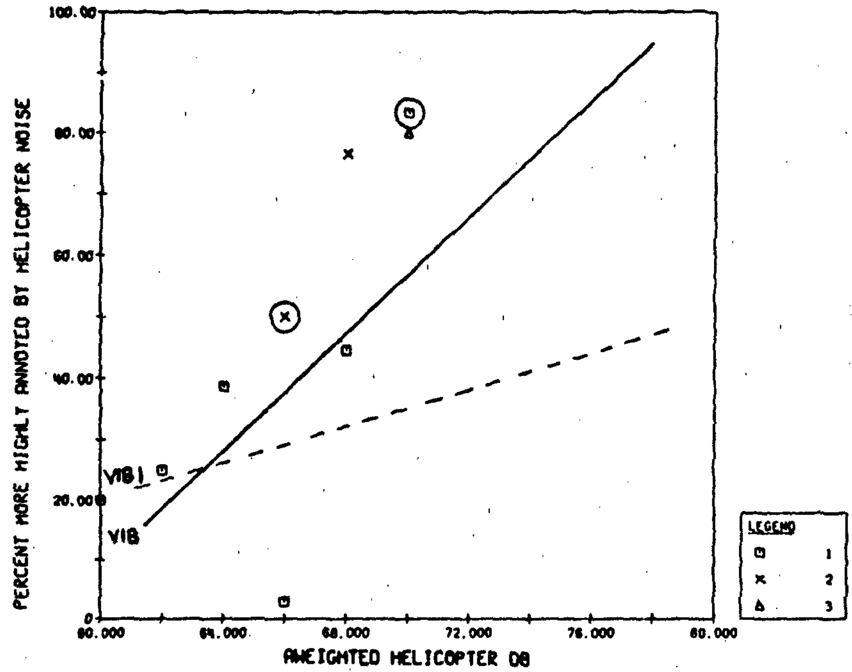


Figure C9. A-weighted living room; white noise 64 to 68 dB.

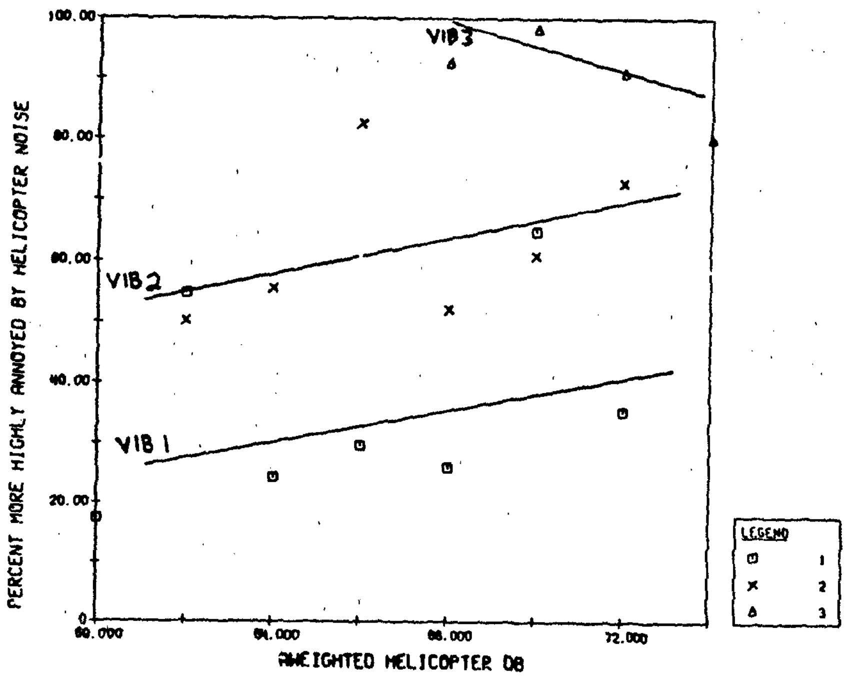


Figure C10. A-weighted living room; white noise 68 to 72 dB.

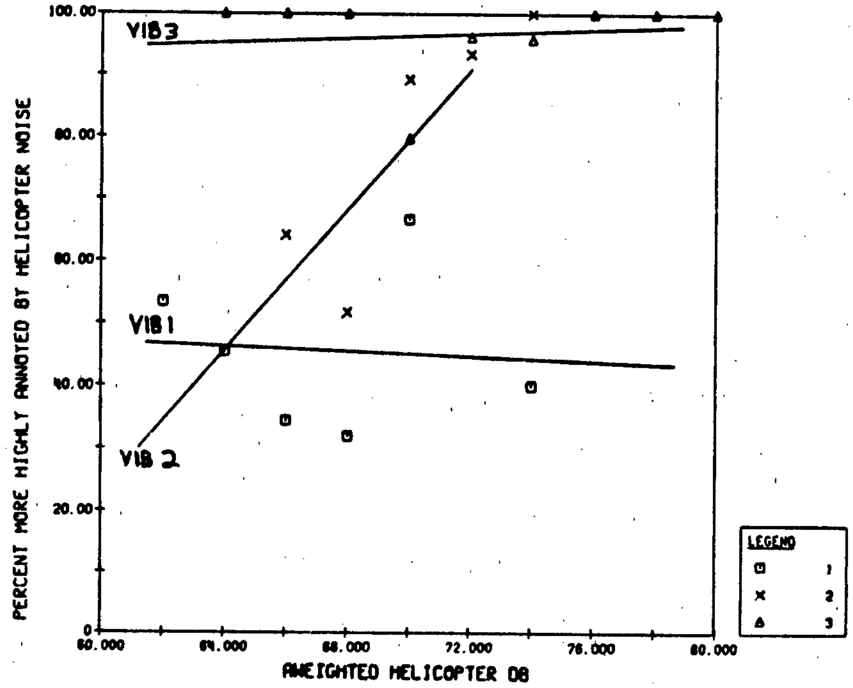


Figure C11. A-weighted living room; white noise 72 to 76 dB.

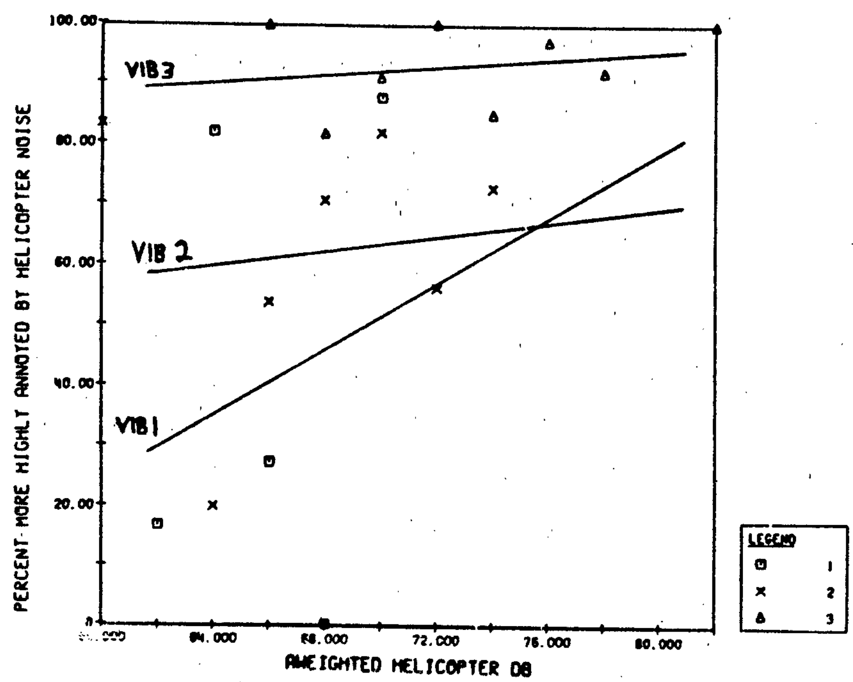


Figure C12. A-weighted living room; white noise 76 to 80 dB.

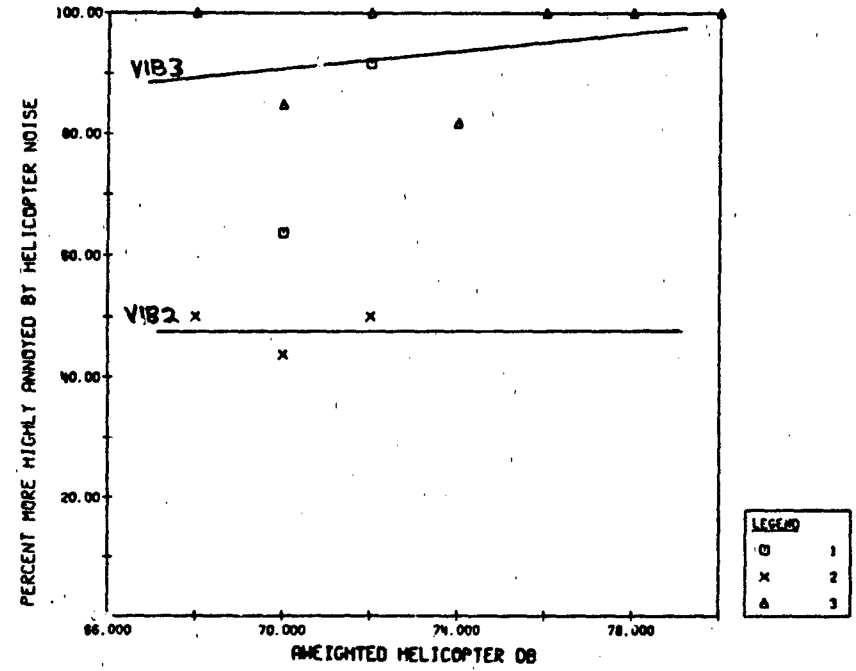


Figure C13. A-weighted living room; white noise 80 to 84 dB.

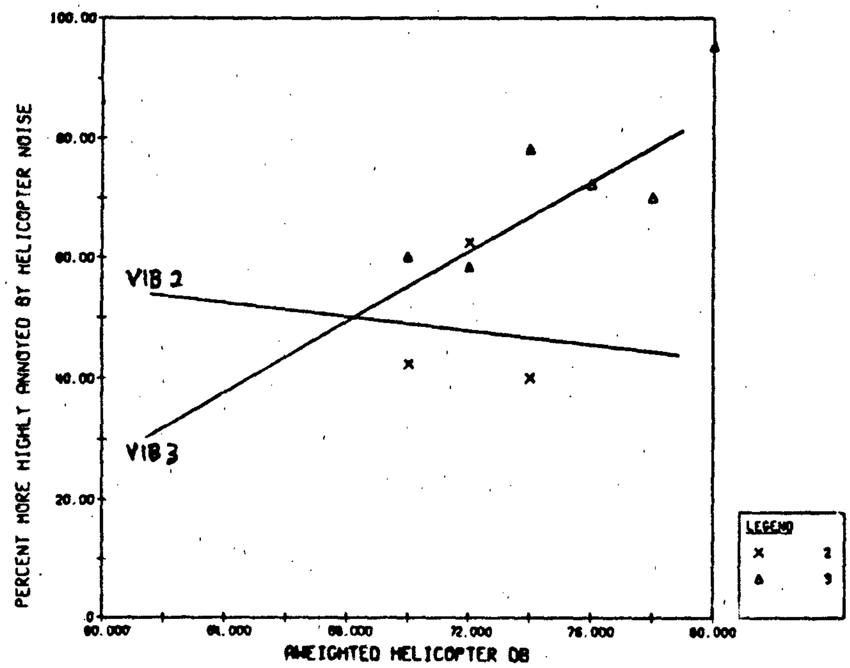


Figure C14. A-weighted living room; white noise 84 to 88 dB.

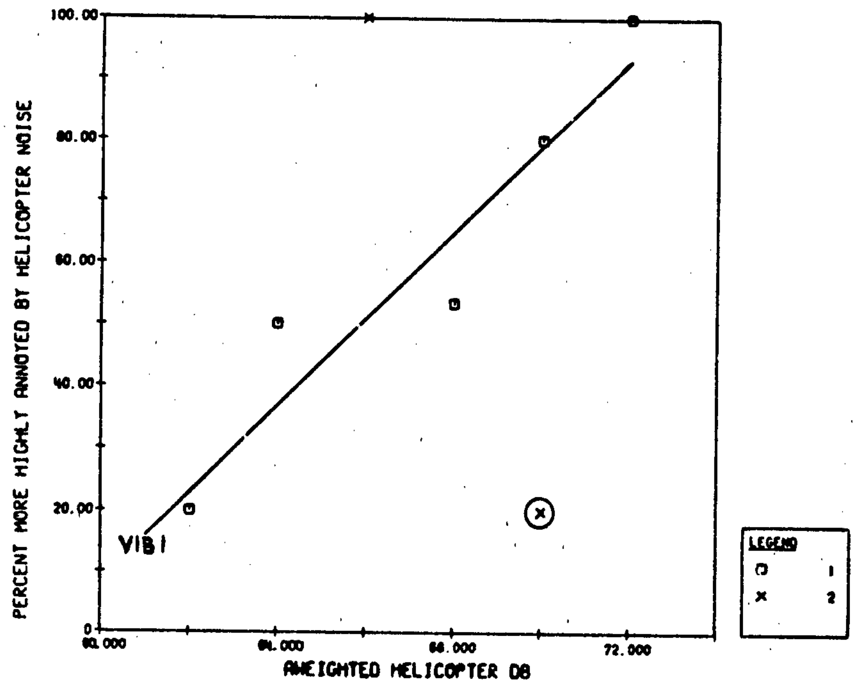


Figure C15. A-weighted dining room; white noise 64 to 68 dB.

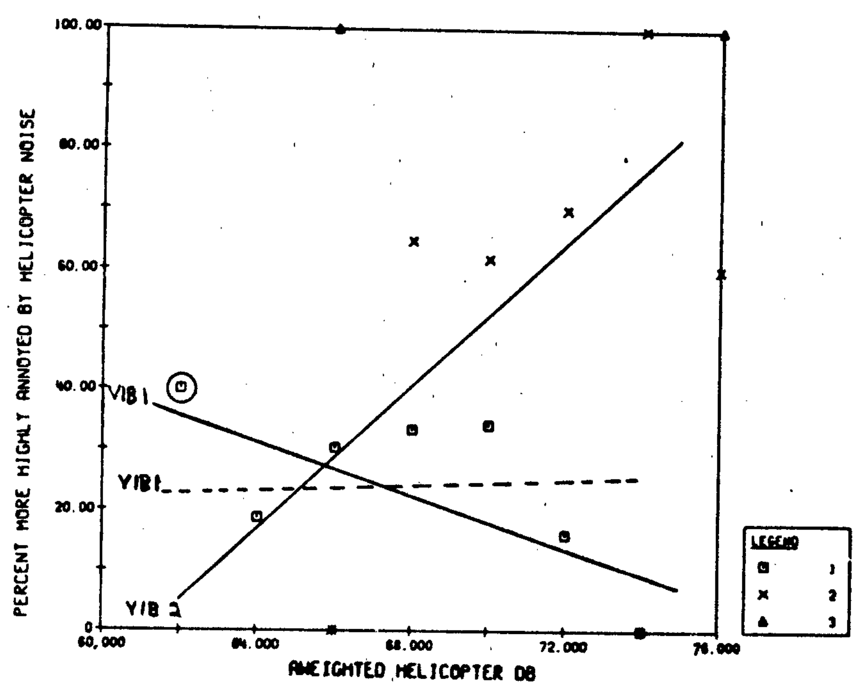


Figure C16. A-weighted dining room; white noise 68 to 72 dB.

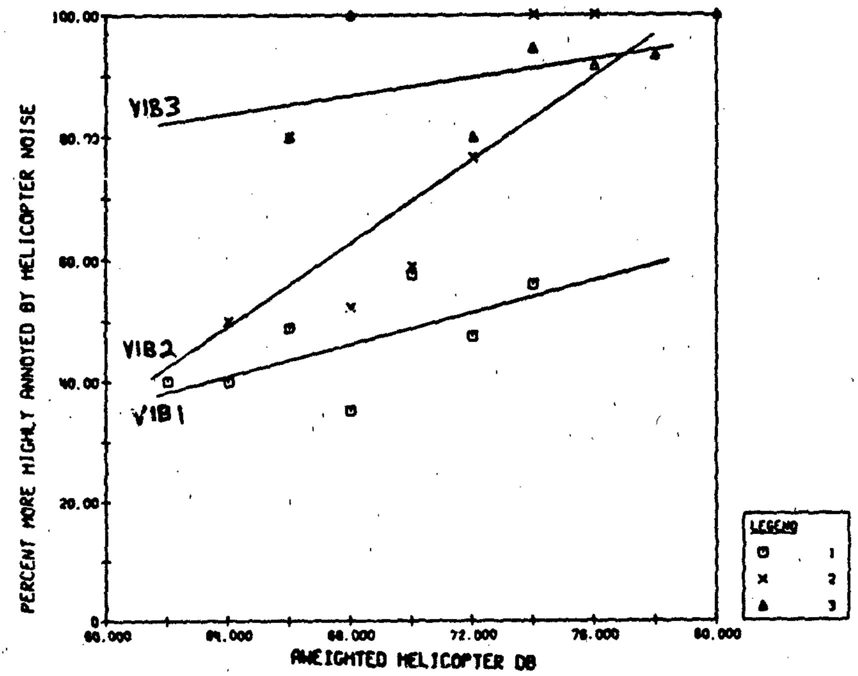


Figure C17. A-weighted dining room; white noise 72 to 76 dB.

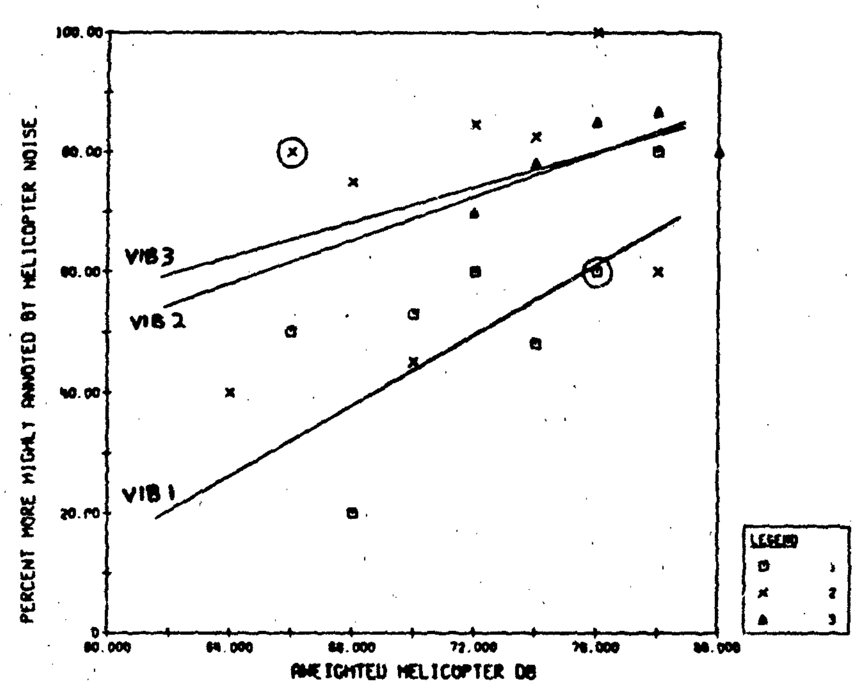


Figure C18. A-weighted dining room; white noise 76 to 80 dB.

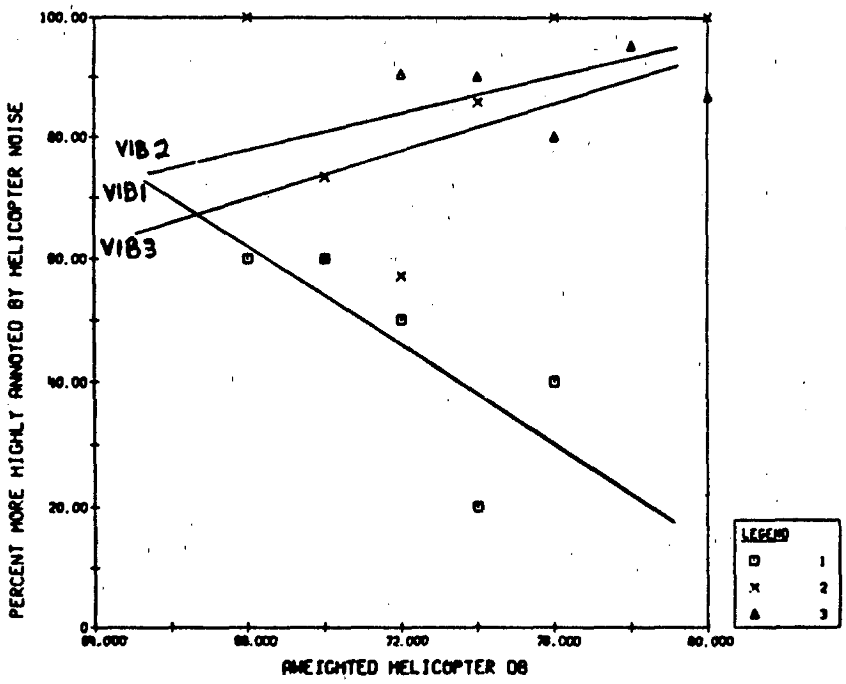


Figure C19. A-weighted dining room; white noise 80 to 84 dB.

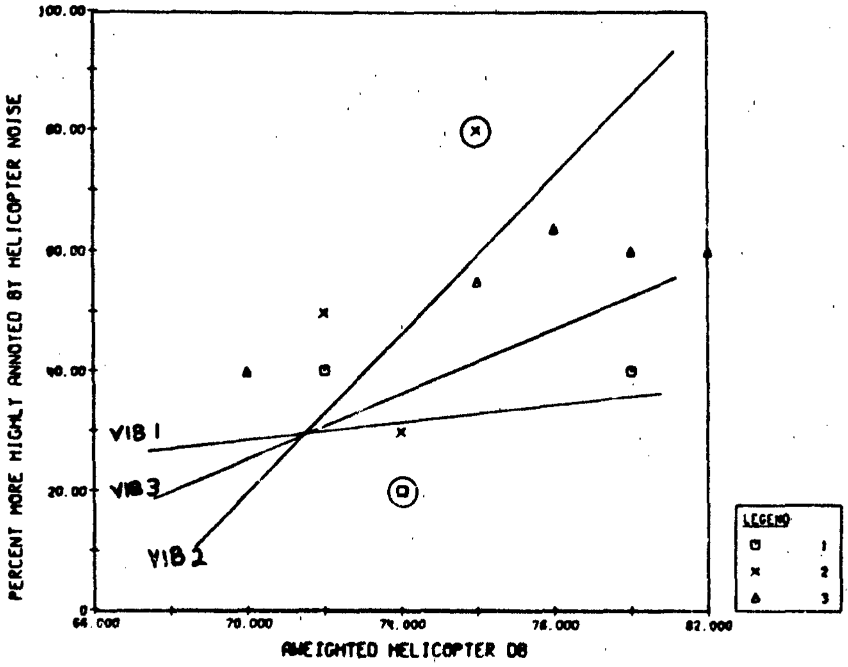


Figure C20. A-weighted dining room; white noise 84 to 88 dB.

APPENDIX D:

SUBJECT RESPONSE RESULTS BY A-WEIGHTED HELICOPTER SEL

Figures D1 through D21 contain the consolidated subject response by A-weighted helicopter SEL for various 4-dB-wide control SELs. The data are for:

1. The tent

2. The total mobile home

3. The liv-din in the house split on three vibration levels as reported subjectively by the USA-CERL researcher.

Regression lines (solid) are fit to the data when three or more data points exist.

Data for which the number of subjects is less than 1.5 times the average difficulty number (subjects reported difficulty in deciding on a 5-point scale--see Appendix A) are circled. When it appears to be significant, an approximate new regression line (dashed) is fit to data sets that have one or more circled points, provided at least three uncircled data points remain.

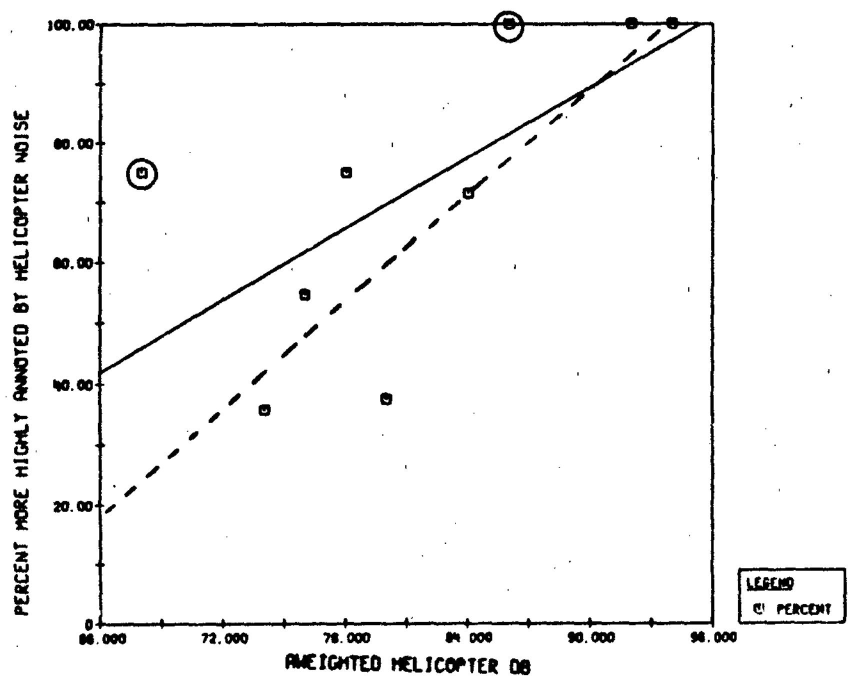


Figure D1. A-weighted tent; white noise 80 to 84 dB.

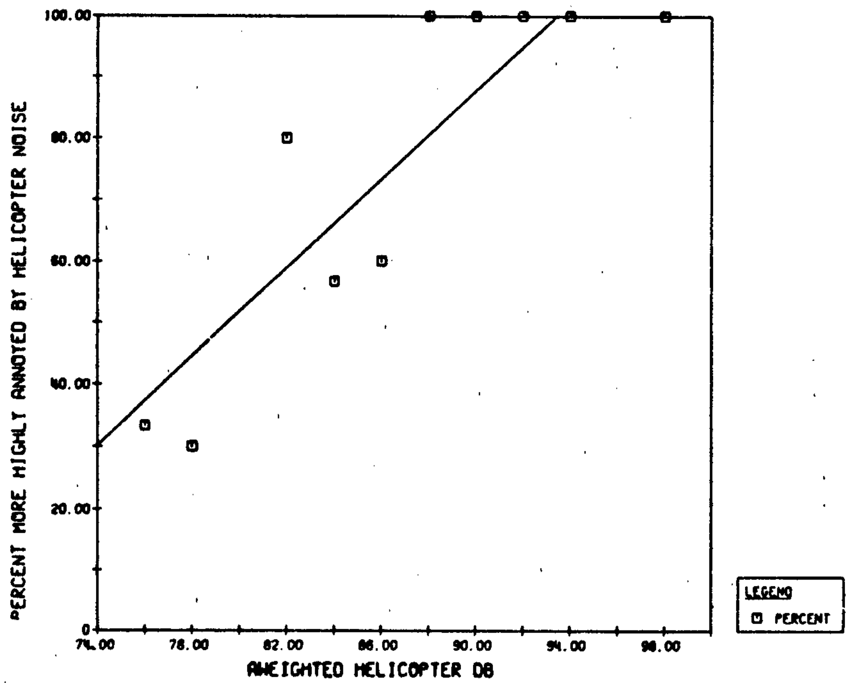


Figure D2. A-weighted tent; white noise 84 to 88 dB.

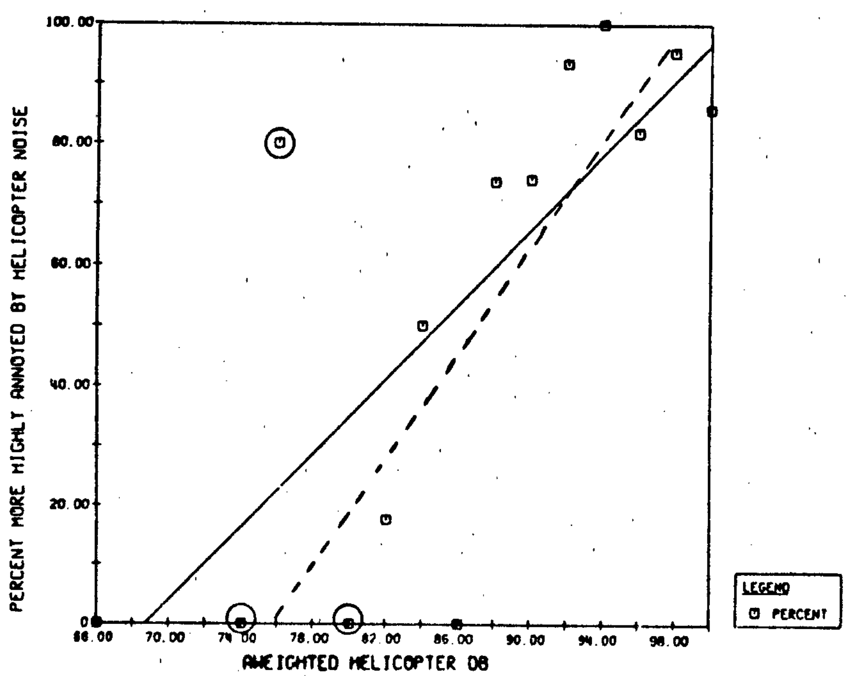


Figure D3. A-weighted tent; white noise 88 to 92 dB.

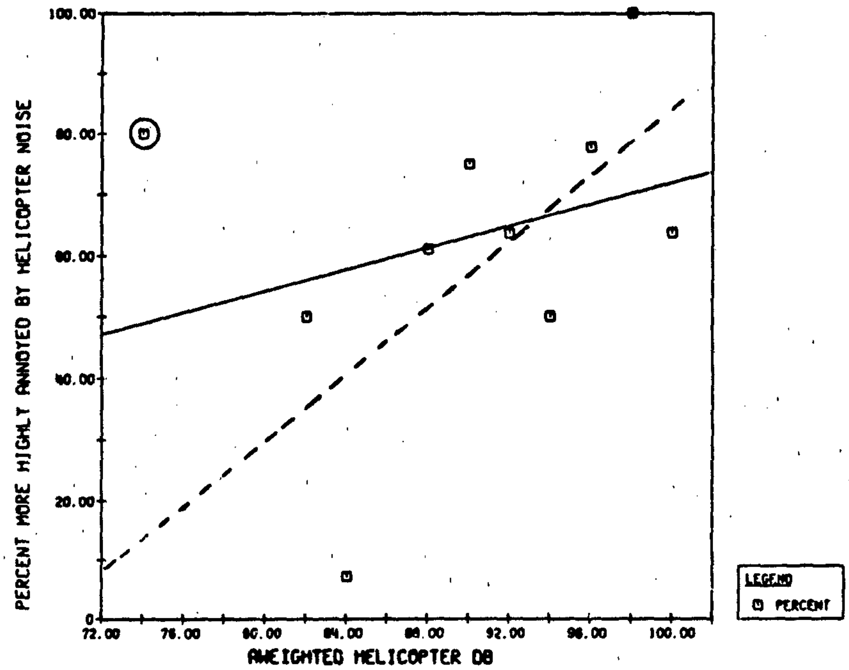


Figure D4. A-weighted tent; white noise 92 to 96 dB.

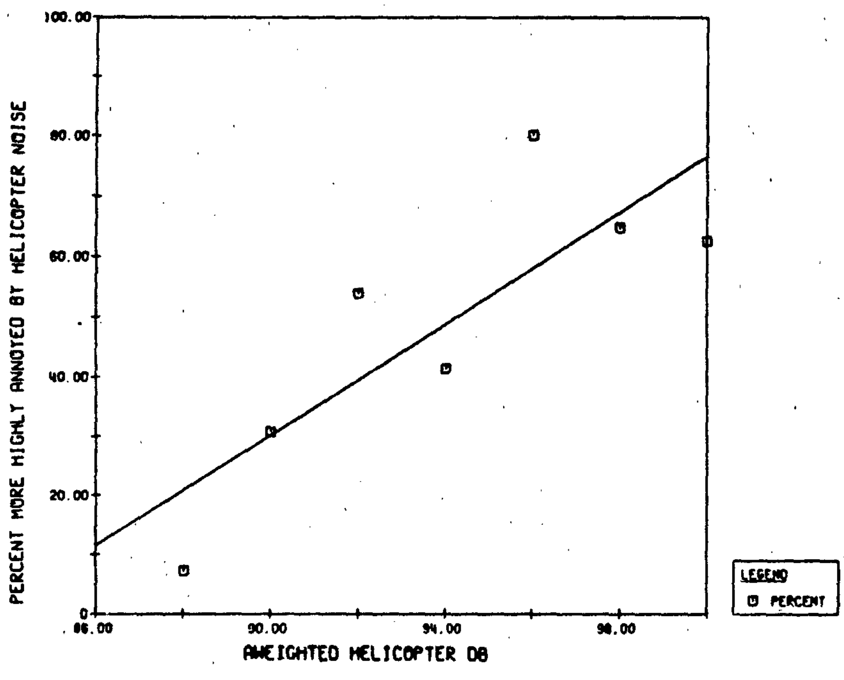


Figure D5. A-weighted tent; white noise 96 to 100 dB.

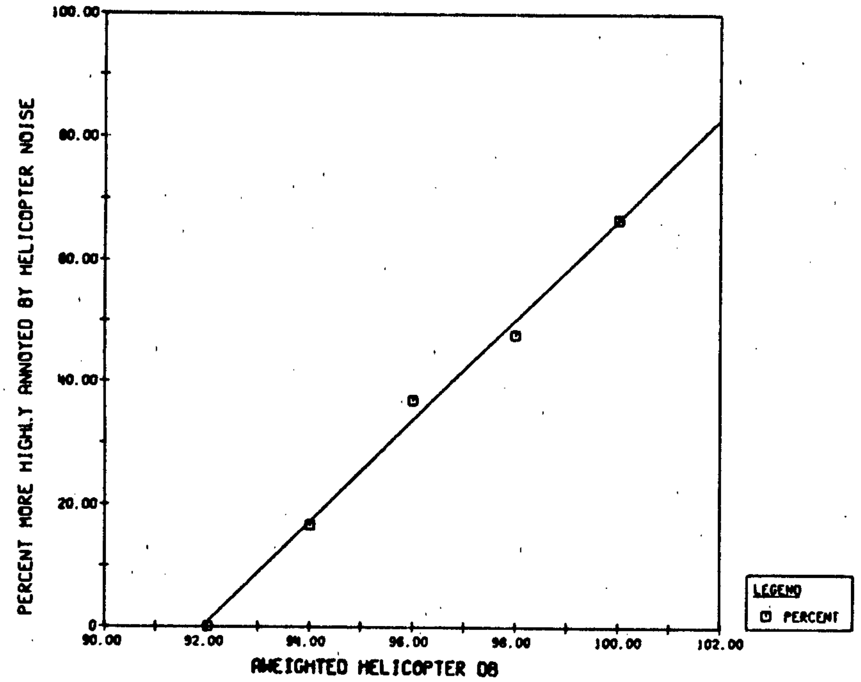


Figure D6. A-weighted tent; white noise 100 to 104 dB.

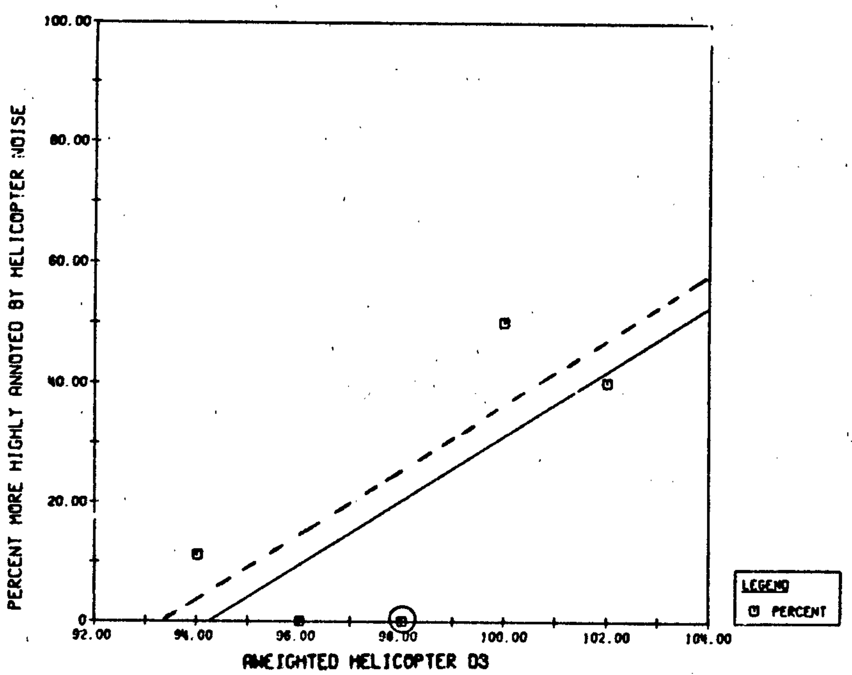


Figure D7. A-weighted tent; white noise 104 to 108 dB.

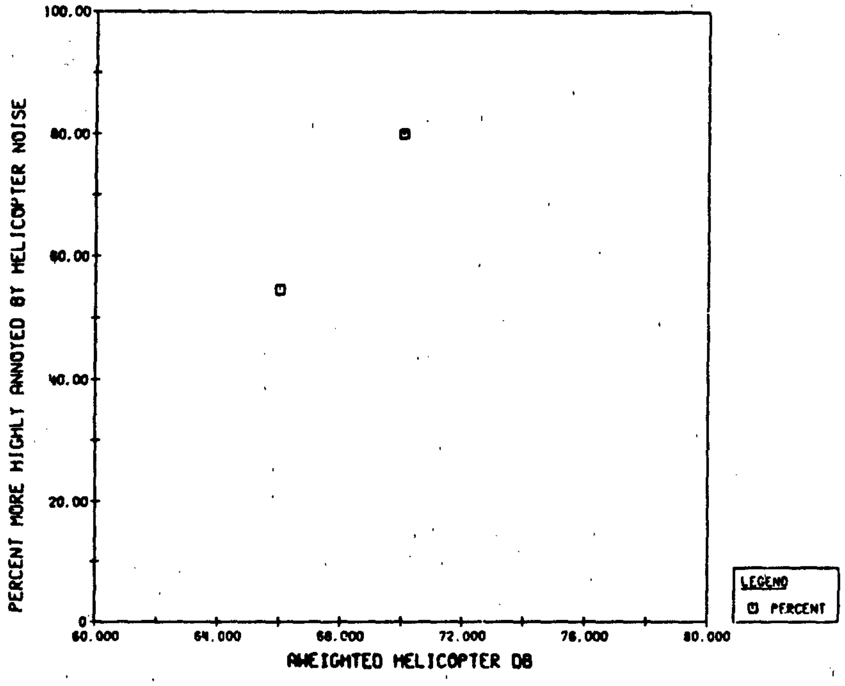


Figure D8. A-weighted total mobile home; white noise 60 to 64 dB.

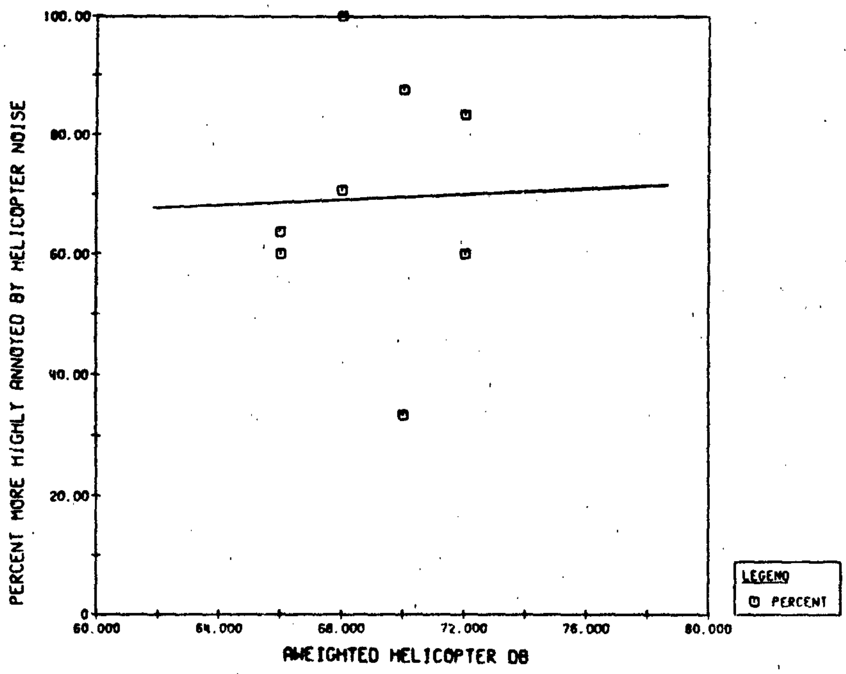


Figure D9. A-weighted total mobile home; white noise 64 to 68 dB.

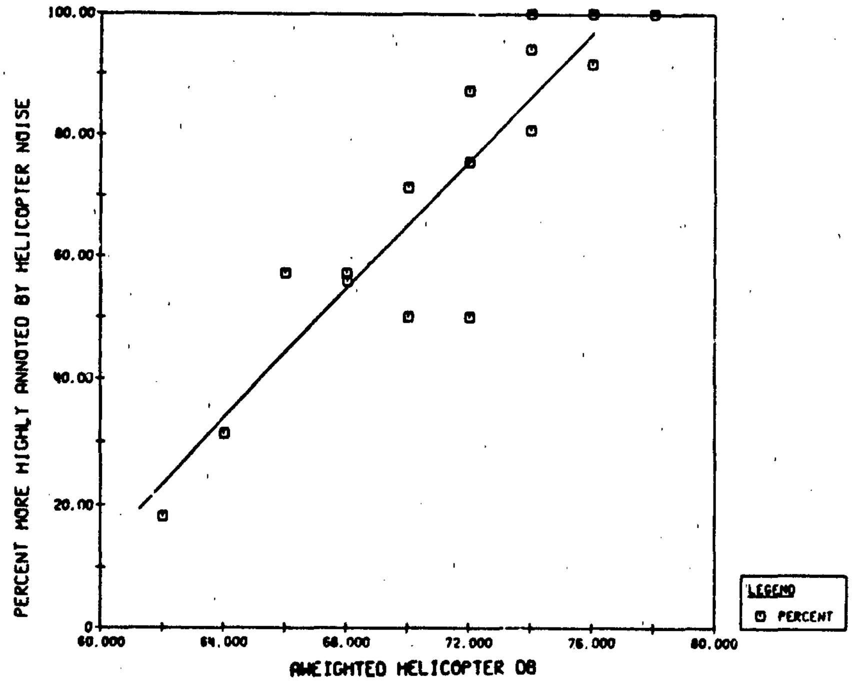


Figure D10. A-weighted total mobile home; white noise 68 to 72 dB.

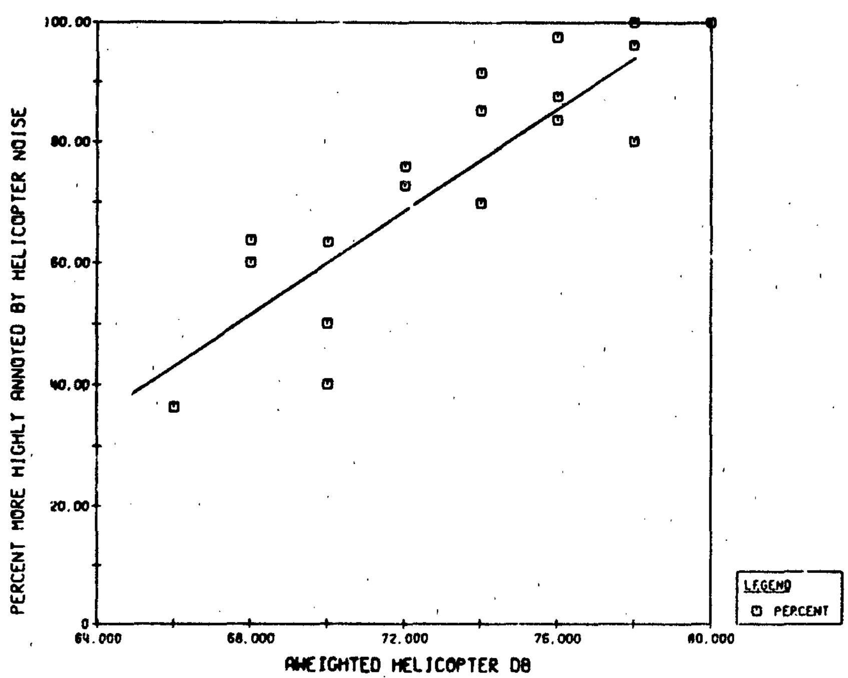


Figure D11. A-weighted total mobile home; white noise 72 to 76 dB.

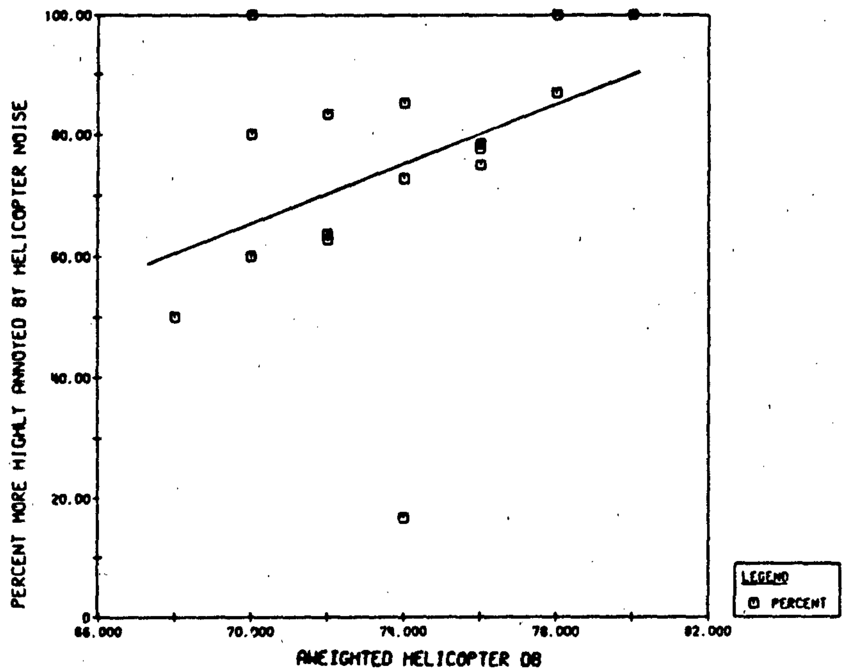


Figure D12. A-weighted total mobile home; white noise 76 to 80 dB.

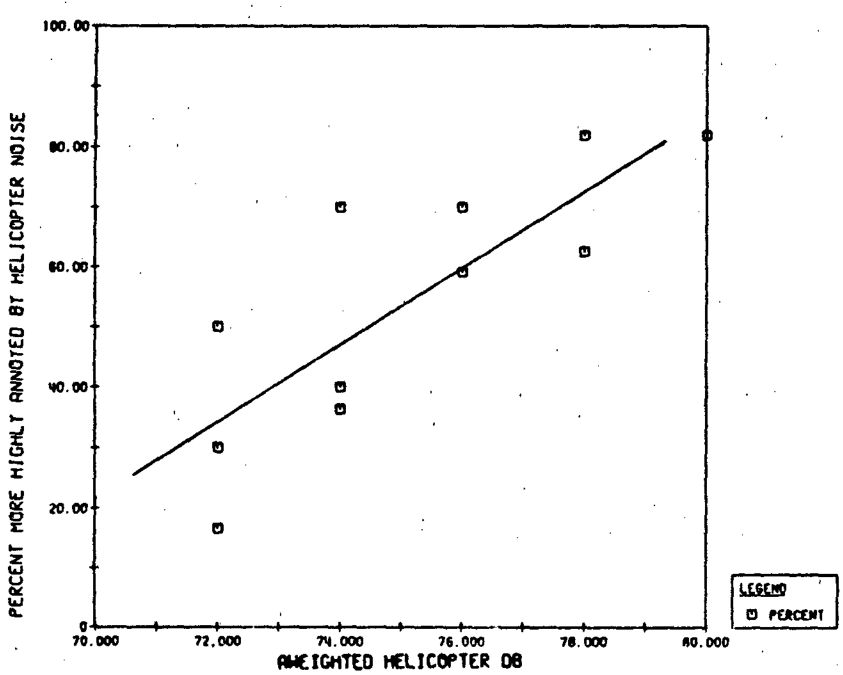


Figure D13 A-weighted total mobile home; white noise 80 to 84 dB.

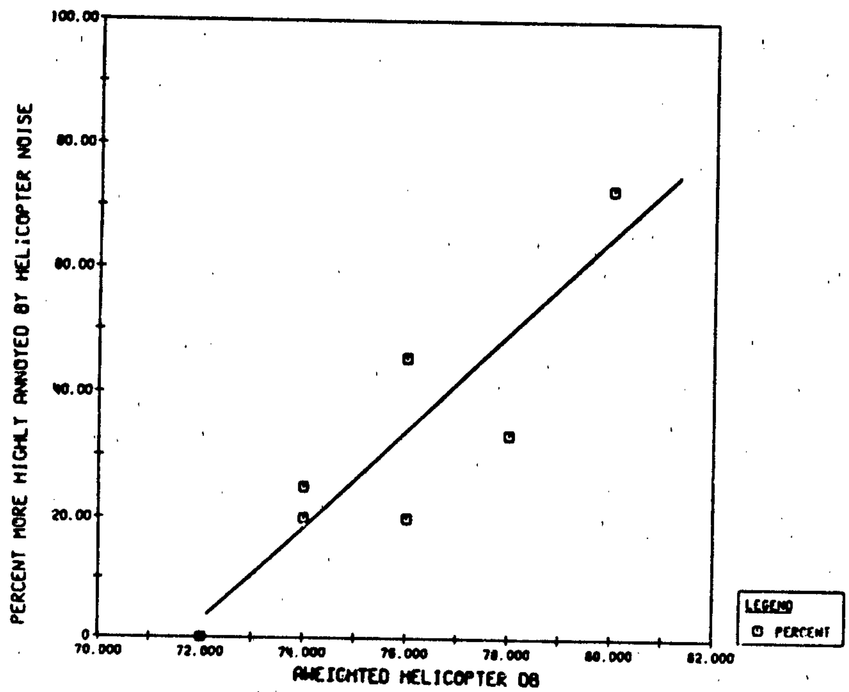


Figure D14. A-weighted total mobile home; white noise 84 to 88 dB.

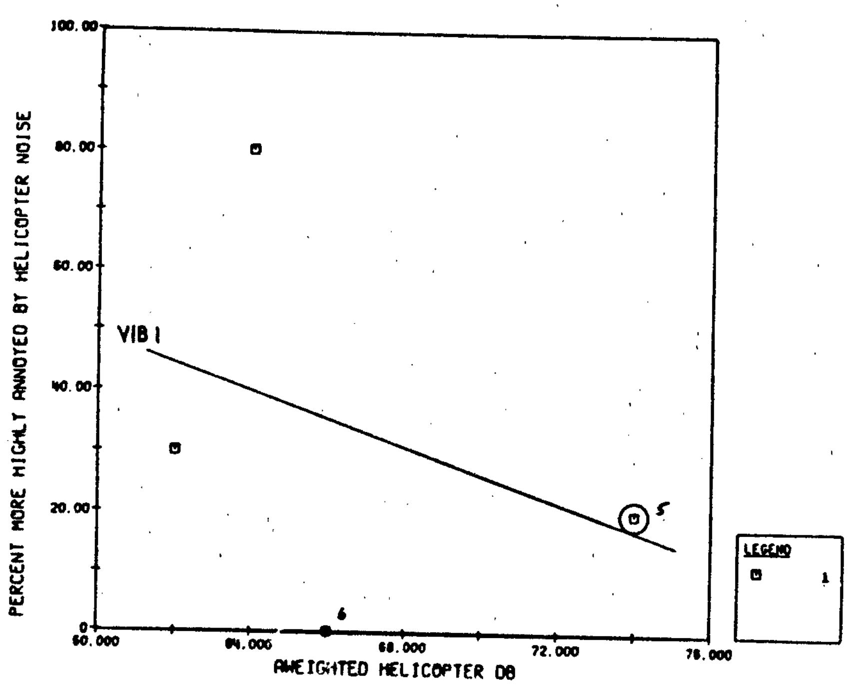


Figure D15. A-weighted living/dining room; white noise 60 to 64 dB.

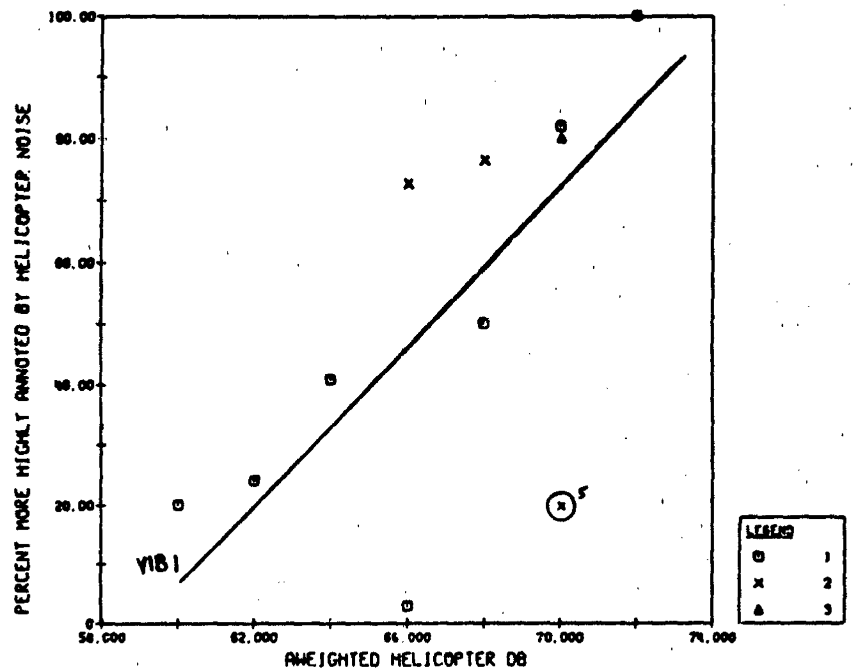


Figure D16. A-weighted living/dining room; white noise 64 to 68 dB.

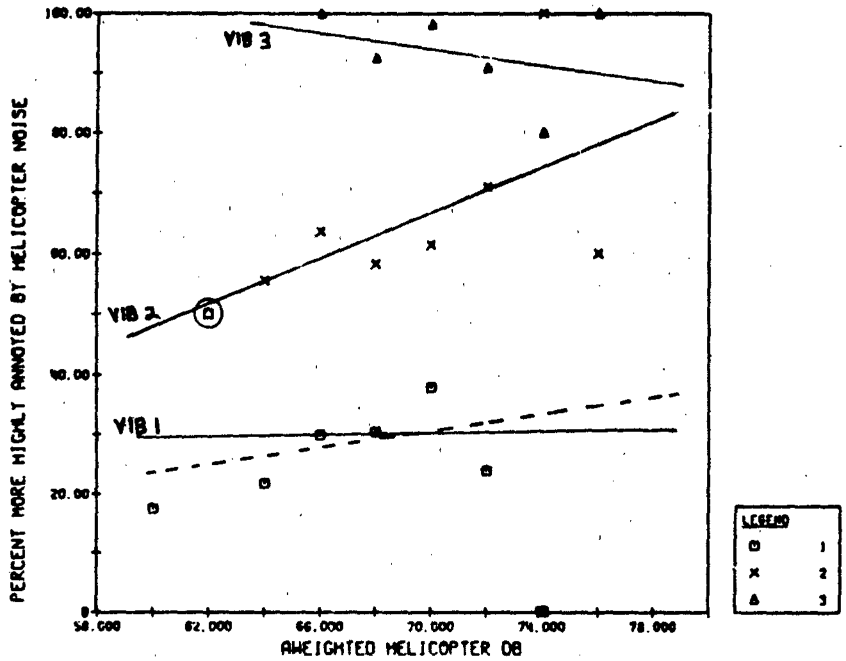


Figure D17. A-weighted living/dining room; white noise 68 to 72 dB.

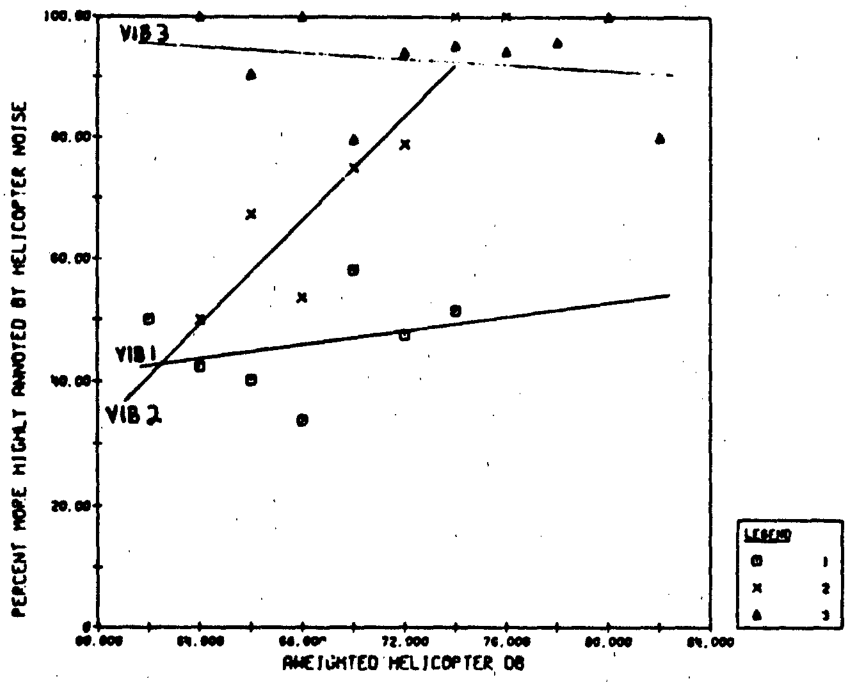


Figure D18. A-weighted living/dining room; white noise 72 to 76 dB.

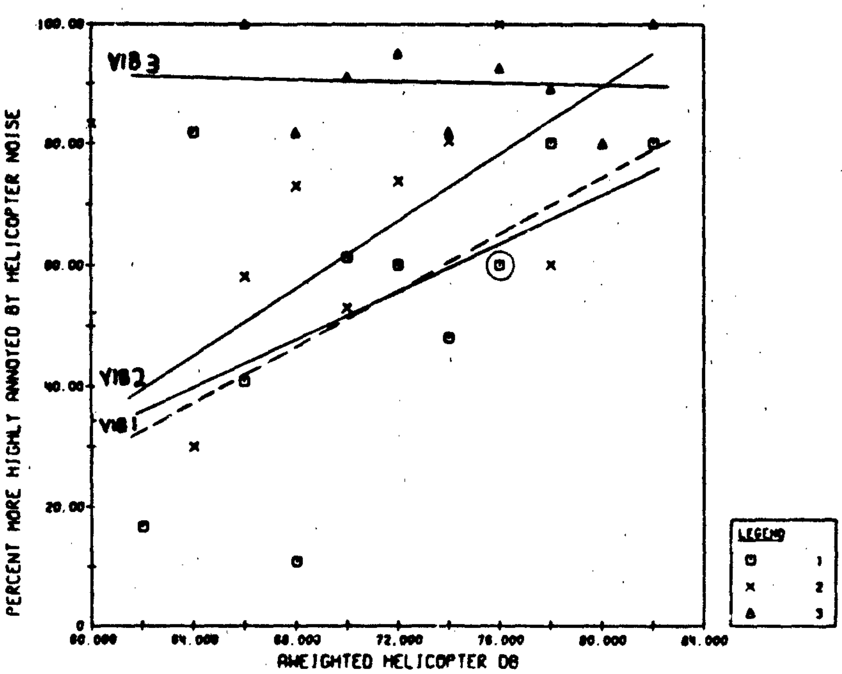


Figure D19. A-weighted living/dining room; white noise 80 to 84 dB.

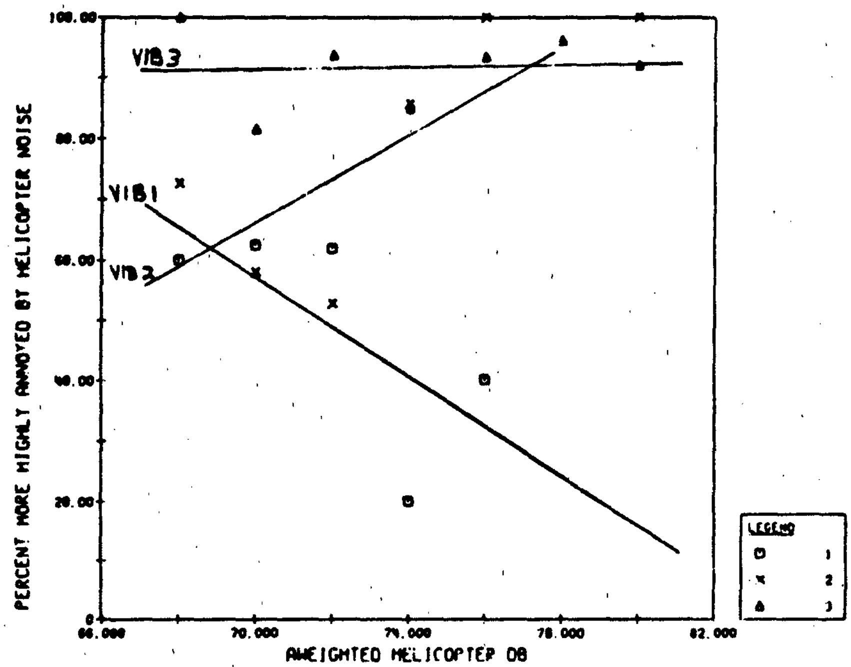


Figure D20. A-weighted living/dining room; white noise 80 to 84 dB.

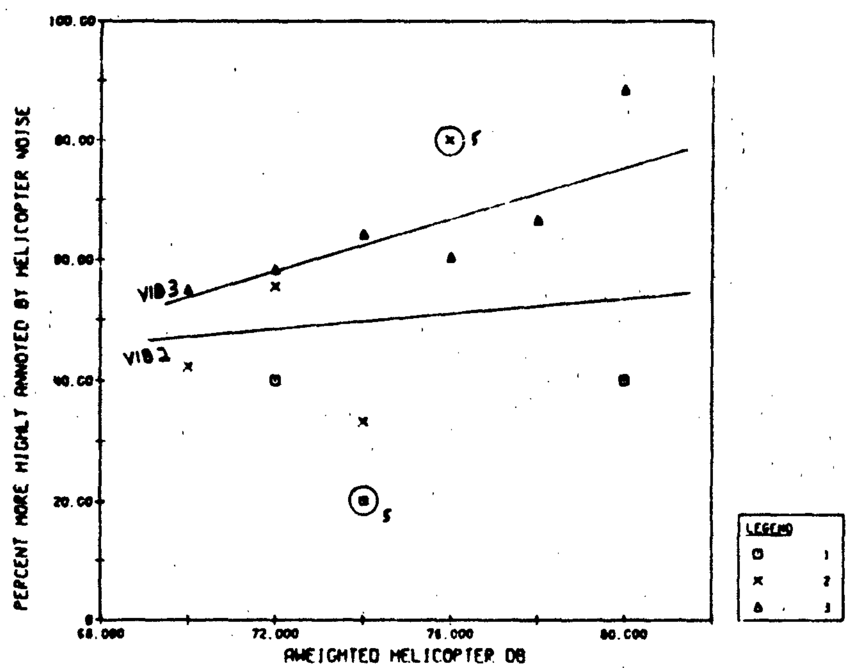


Figure D21. A-weighted living/dining room; white noise 84 to 88 dB.

APPENDIX E:

SUBJECT RESPONSE RESULTS BY C-WEIGHTED INDOOR HELICOPTER SEL AND BY A- AND C-WEIGHTED OUTDOOR HELICOPTER SEL

Figures E1 through E21 contain consolidated subject response results for the combined liv-din areas for various 4-dB-wide control SEL bins by C-weighted indoor helicopter SEL and by A- and C-weighted outdoor helicopter SEL.

Only data for which the number of subjects is greater than 1.5 times the average difficulty number (subjects reported difficulty in deciding on a 5-point scale--see Appendix A) are reported. Regression lines are fit to the data when three or more data points exist.

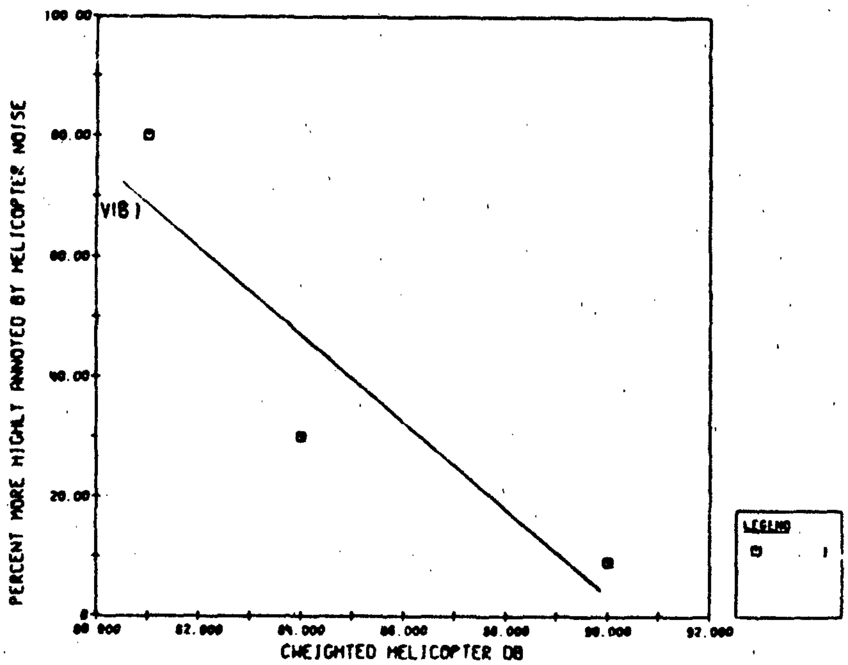


Figure E1. C-weighted living/dining room; white noise 60 to 64 dB.

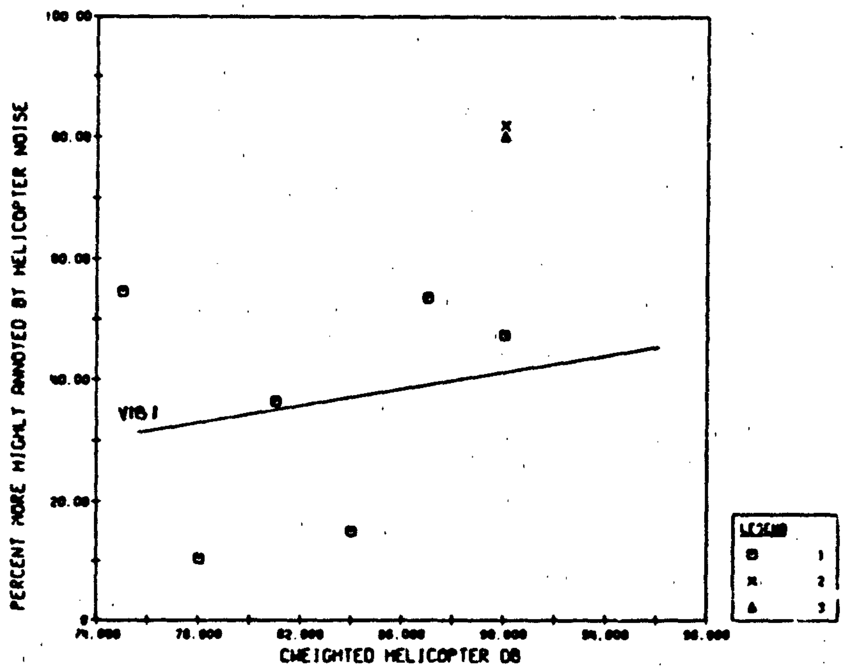


Figure E2. C-weighted living/dining room; white noise 64 to 68 dB.

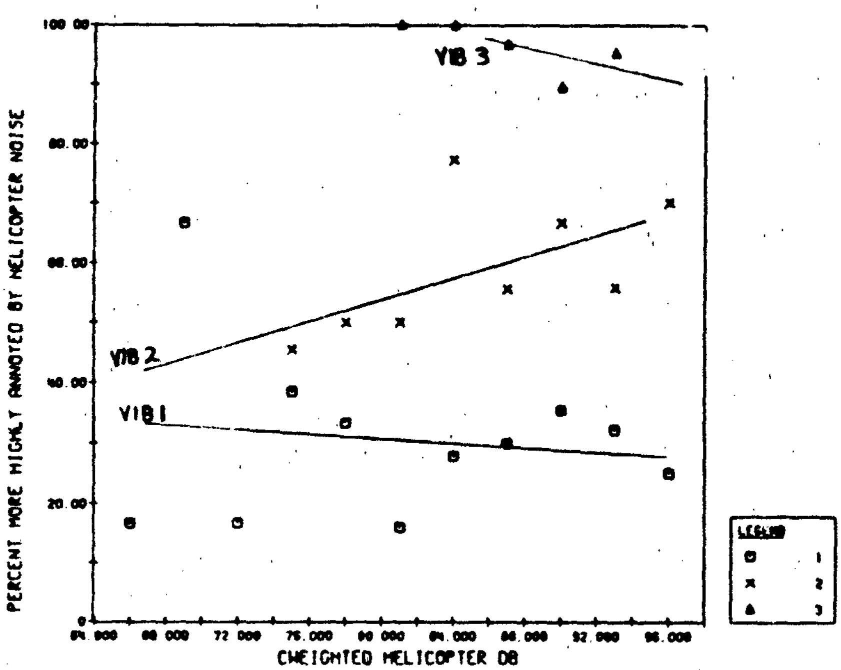


Figure E3. C-weighted living/dining room; white noise 68 to 72 dB.

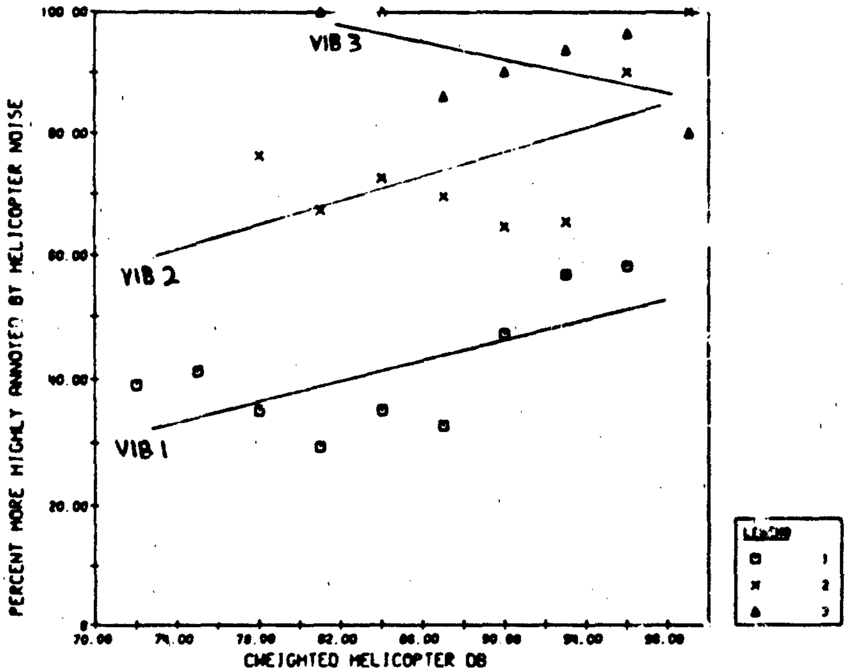


Figure E4. C-weighted living/dining room; white noise 72 to 76 dB.

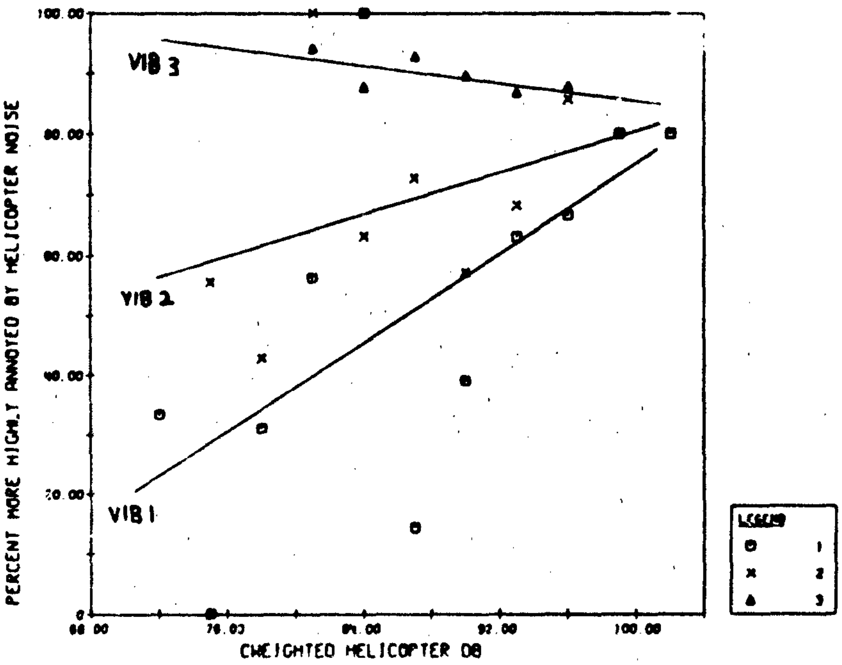


Figure E5. C-weighted living/dining room; white noise 76 to 80 dB.

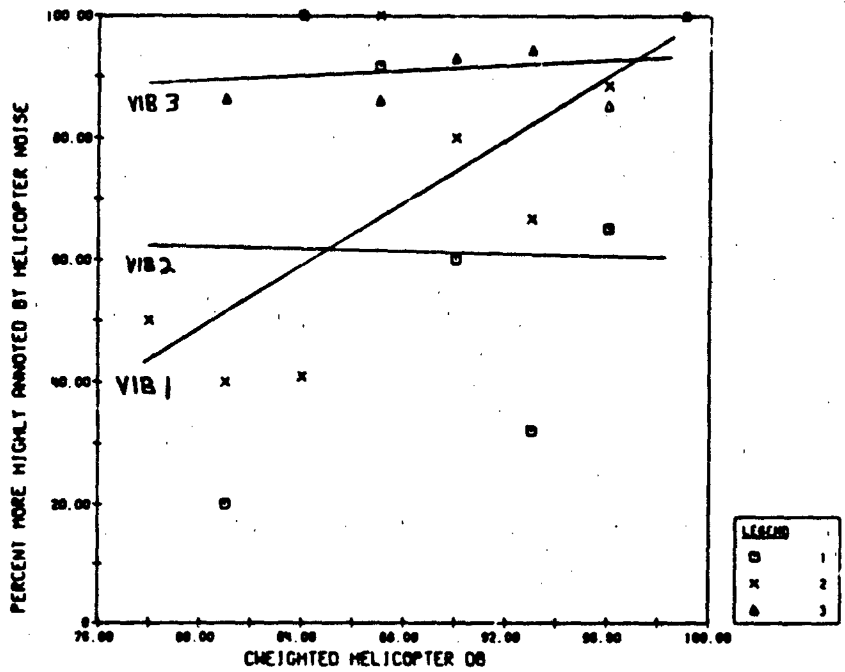


Figure E6. C-weighted living/dining room; white noise 80 to 84 dB.

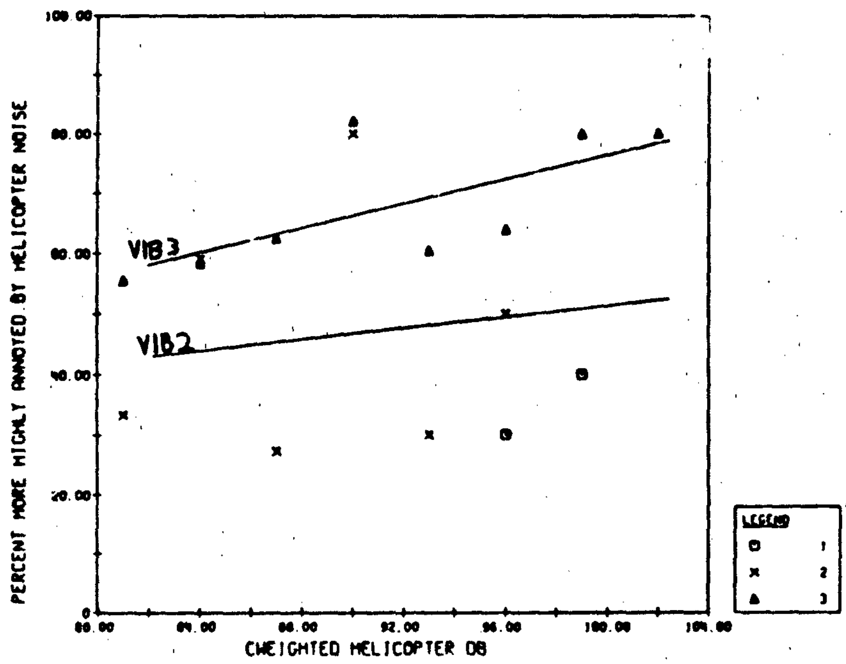


Figure E7. C-weighted living/dining room; white noise 84 to 88 dB.

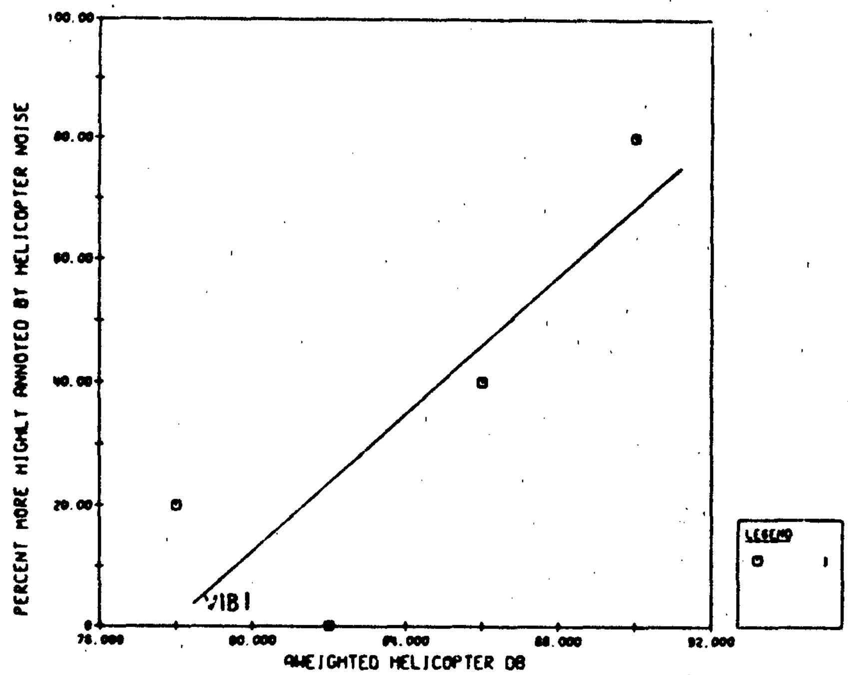


Figure E8. A-weighed living/dining room (tent data); white noise 60 to 64 dB.

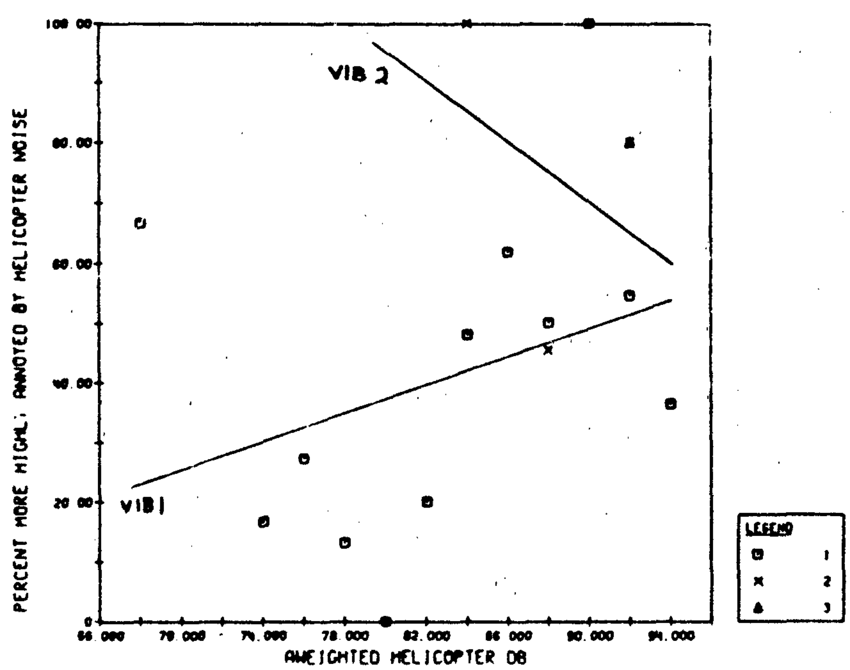


Figure E9. A-weighted living/dining room (tent data); white noise 64 to 68 dB.

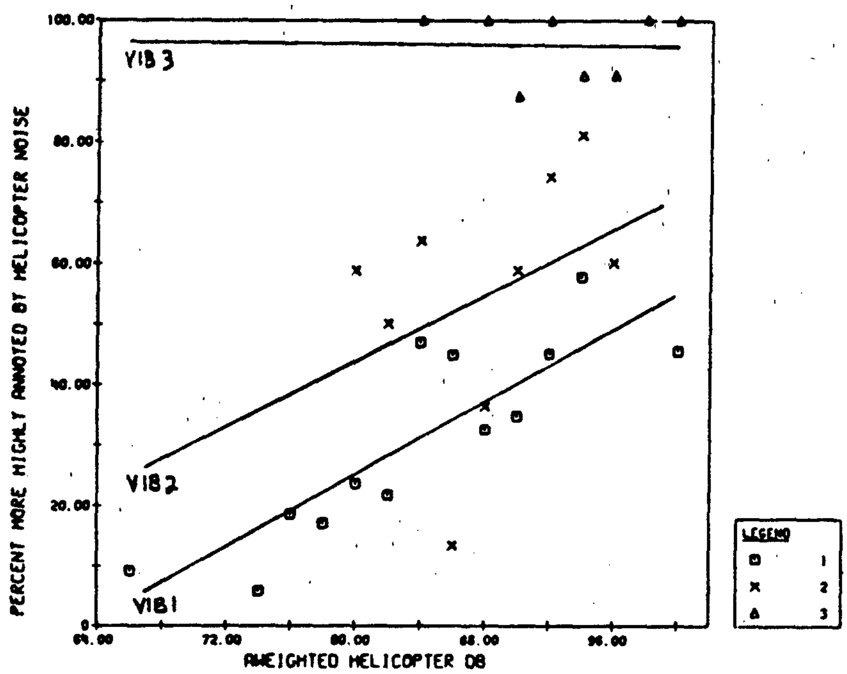


Figure E10. A-weighted living/dining room (tent data); white noise 68 to 72 dB.

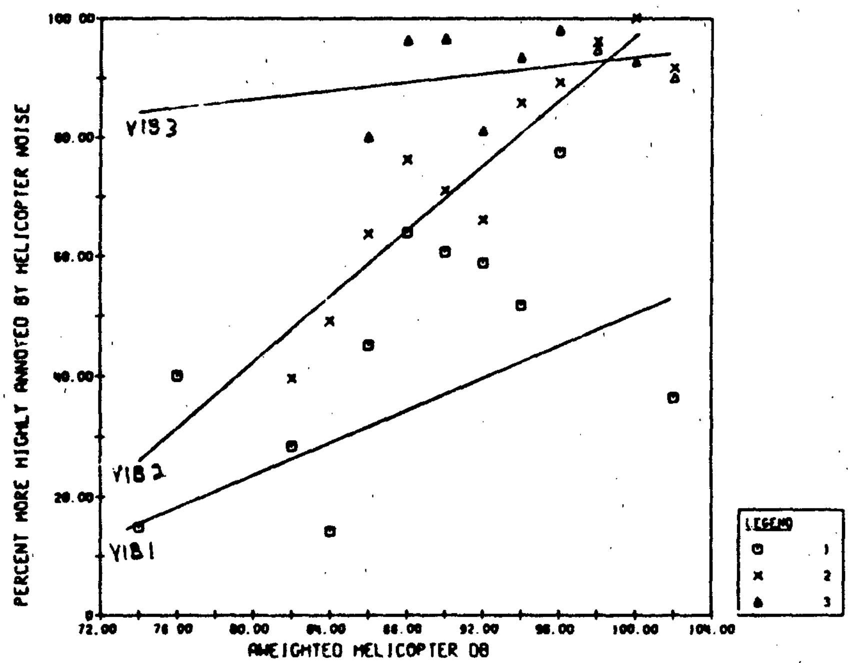


Figure E11. A-weighted living/dining room (tent data); white noise 72 to 76 dB.

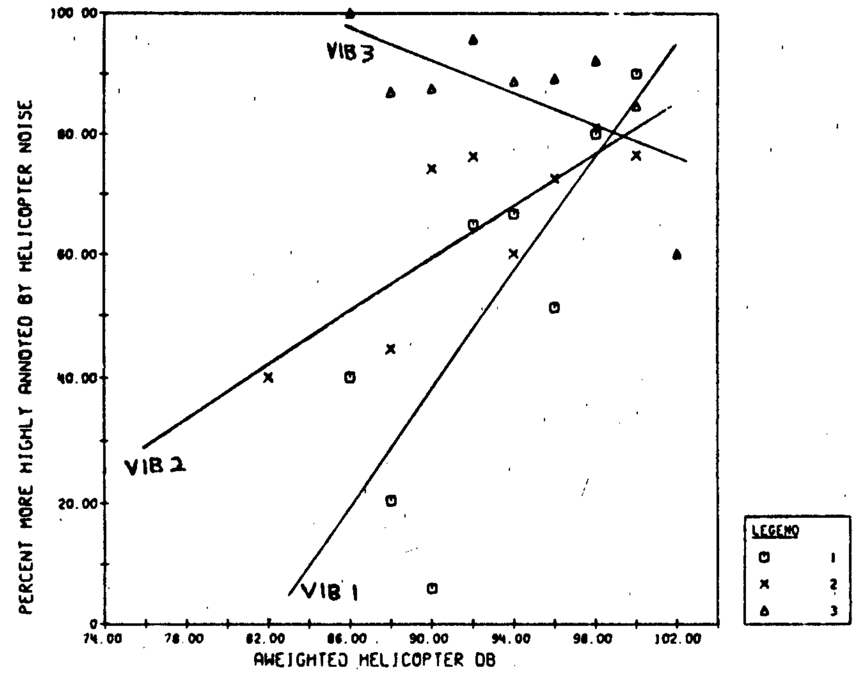


Figure E12. A-weighted living/dining room (tent data); white noise 76 to 80 dB.

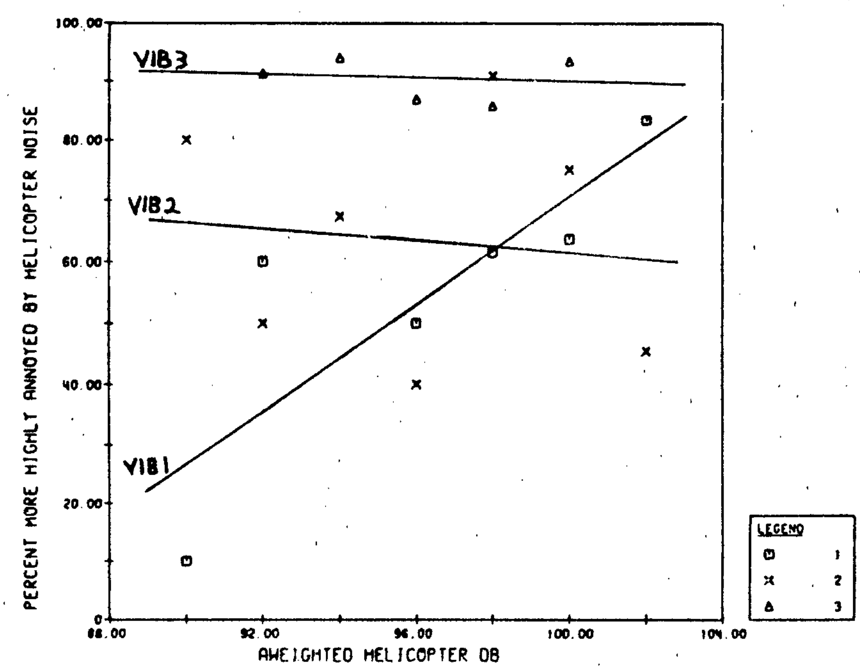


Figure E13. A-weighted living/dining room (tent data); white noise 80 to 84 dB.

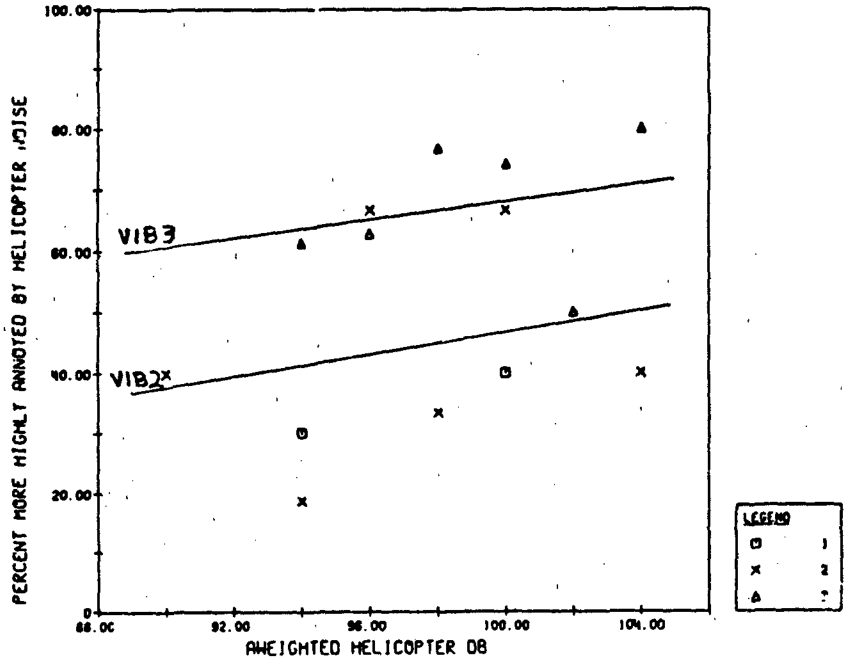


Figure E14. A-weighted living/dining room (tent data); white noise 84 to 88 dB.

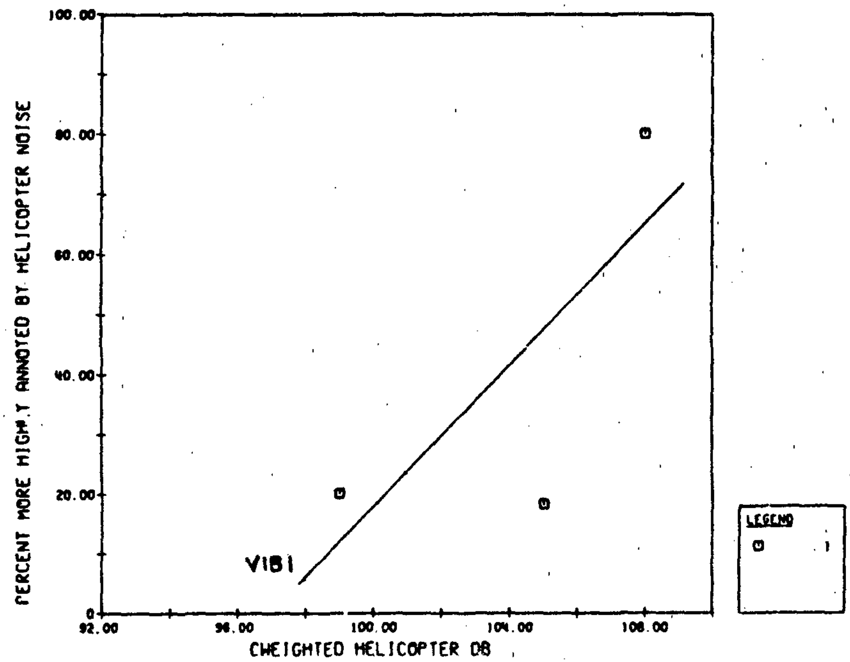


Figure E15. C-weighted living/dining room (tent data); white noise 60 to 64 dB.

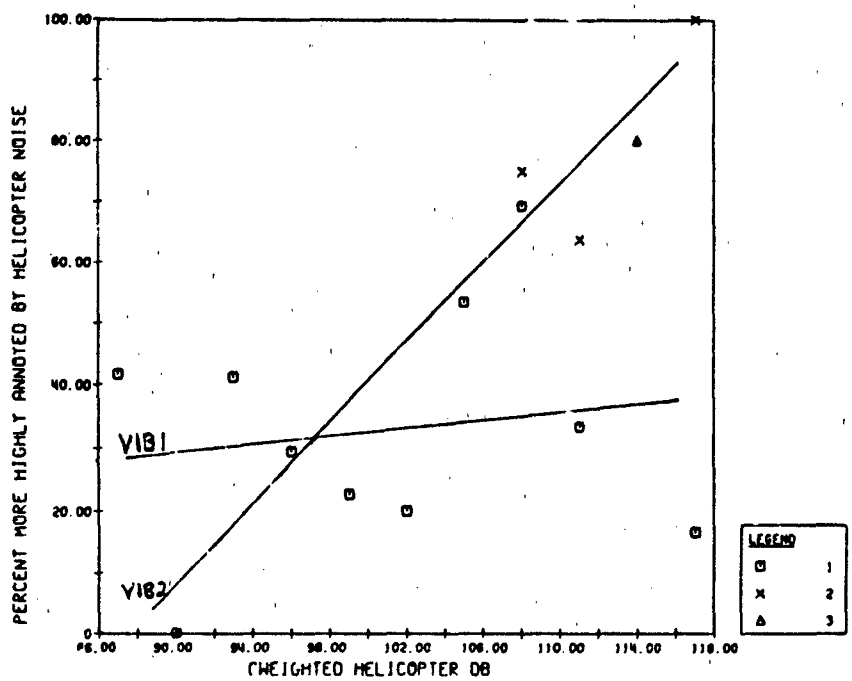


Figure E16. C-weighted living/dining room (tent data); white noise 64 to 68 dB.

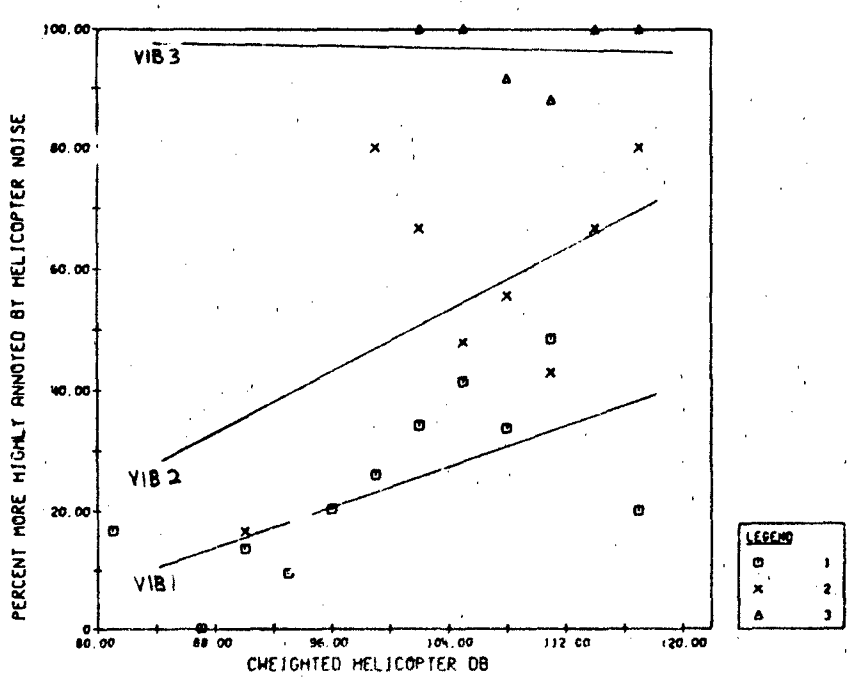


Figure E17. C-weighted living/dining room (tent data); white noise 68 to 72 dB.

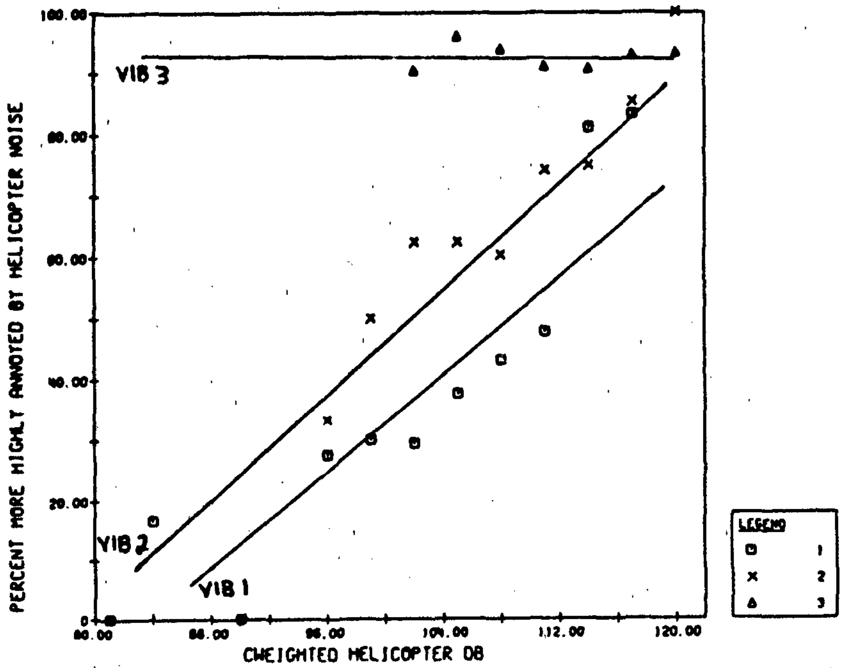


Figure E18. C-weighted living/dining room (tent data); white noise 72 to 76 dB.

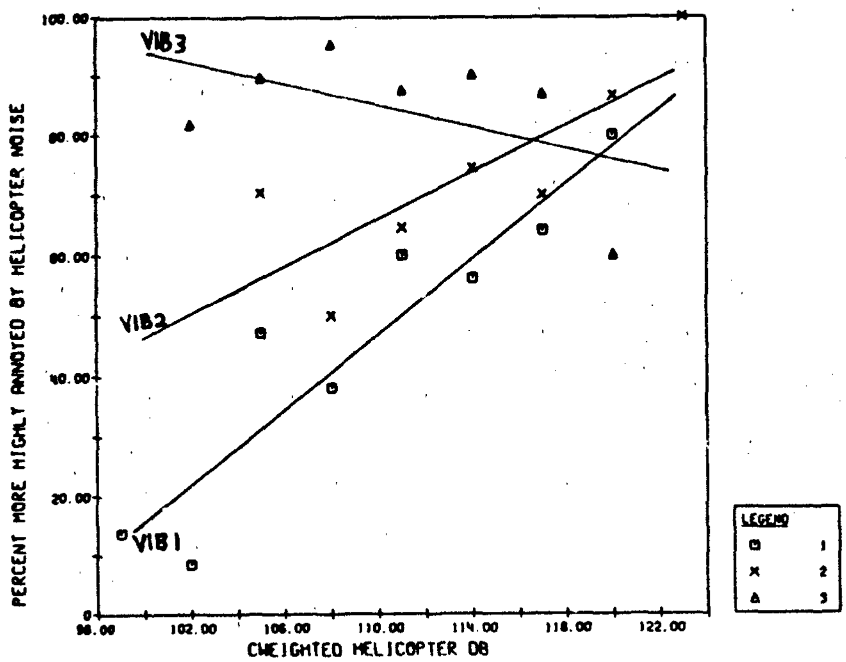


Figure E19. C-weighted living/dining room (tent data); white noise 76 to 80 dB.

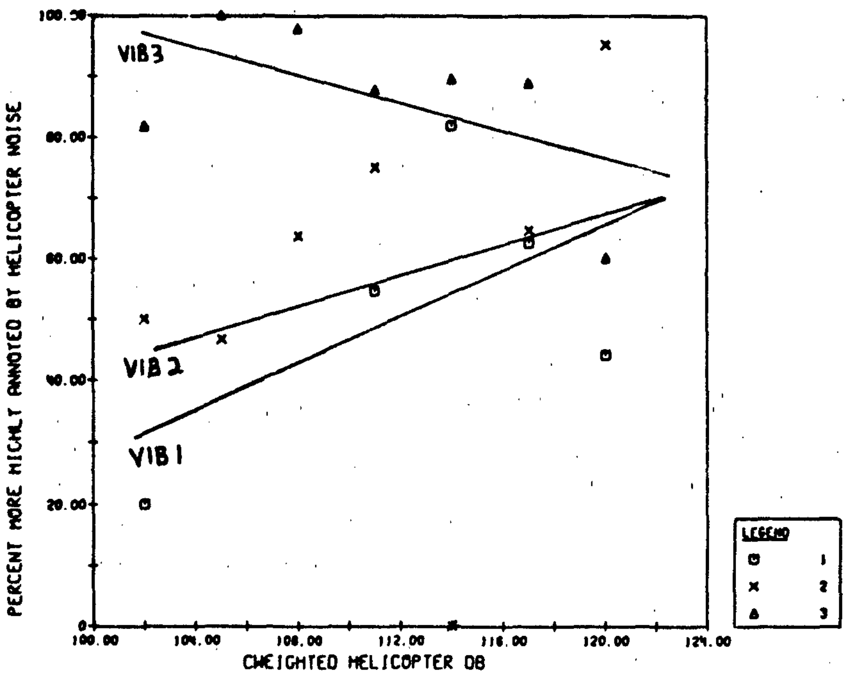


Figure E20. C-weighted living/dining room (tent data); white noise 80 to 84 dB.

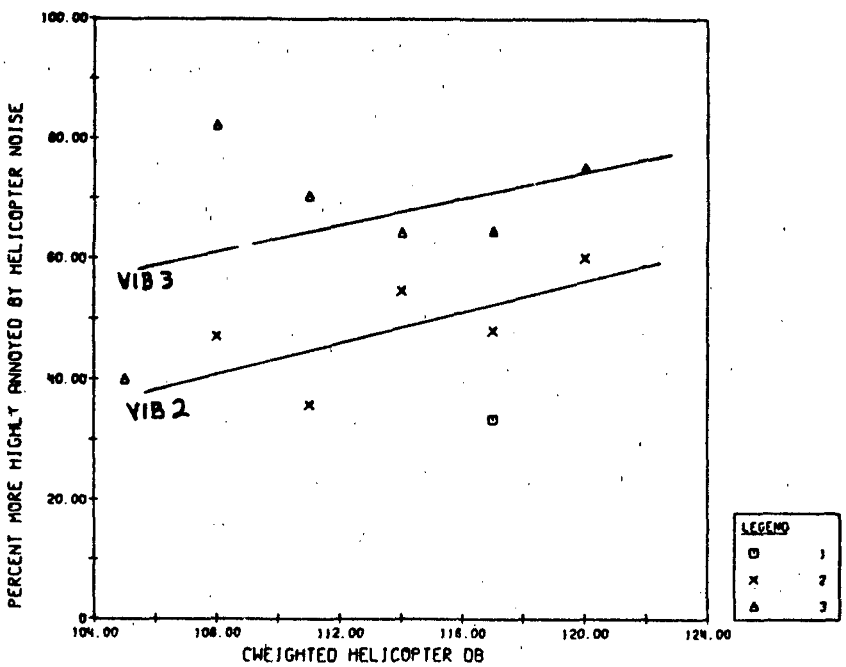


Figure E21. C-weighted living/dining room (tent data); white noise 84 to 88 dB.

APPENDIX F:

CONSOLIDATED SUBJECT RESPONSE RESULTS

Figures F1 through F14 contain consolidated subject response results for the combined liv-din areas for various 4-dB-wide control SEL bins by the difference between C- and A-weighted helicopter SELs indoors and outdoors (tent data).

Only data for which the number of subjects is greater than 1.5 times the average difficulty number are reported (subjects reported difficulty in deciding on a 5-point scale--see Appendix A). Regression lines are fit to the data when three or more data points exist.

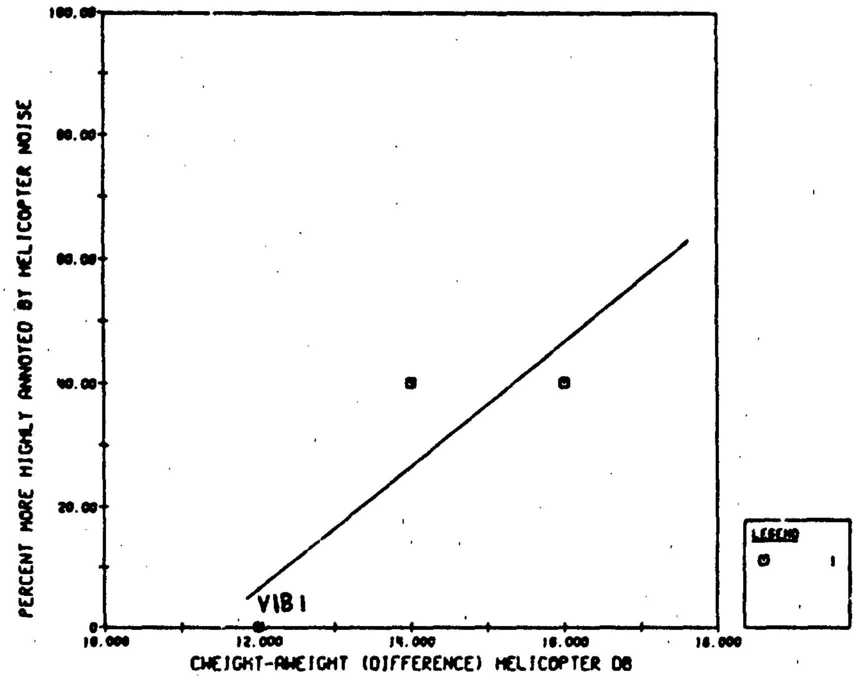


Figure F1. **Living/dining room (tent data); white noise 60 to 64 dB (A-weighted - C-weighted).**

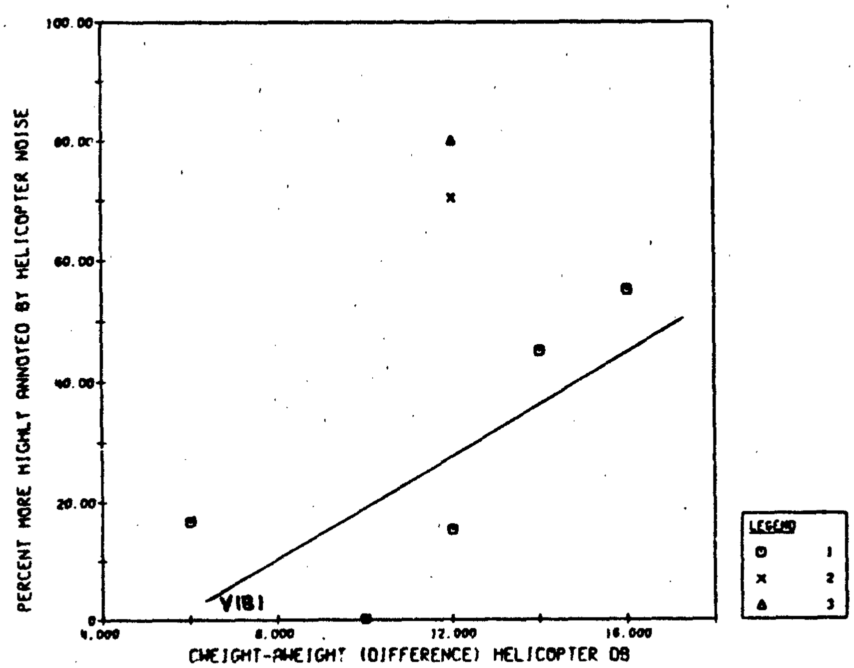


Figure F2. **Living/dining room (tent data); white noise 64 to 68 dB (A-weighted - C-weighted).**

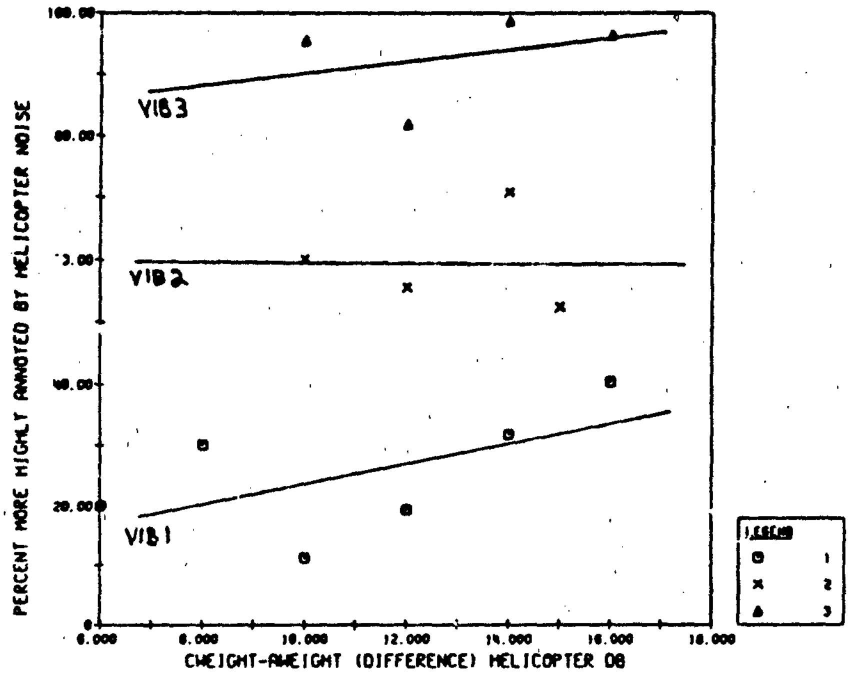


Figure F3. Living/dining room (tent data); white noise 68 to 72 dB (A-weighted - C-weighted).

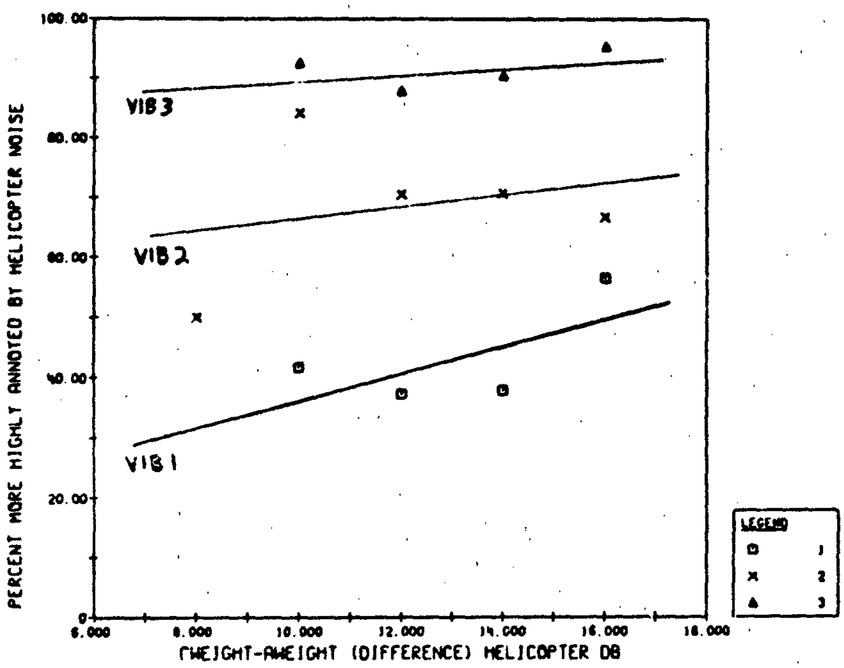


Figure F4. Living/dining room (tent data); white noise 72 to 76 dB (A-weighted - C-weighted).

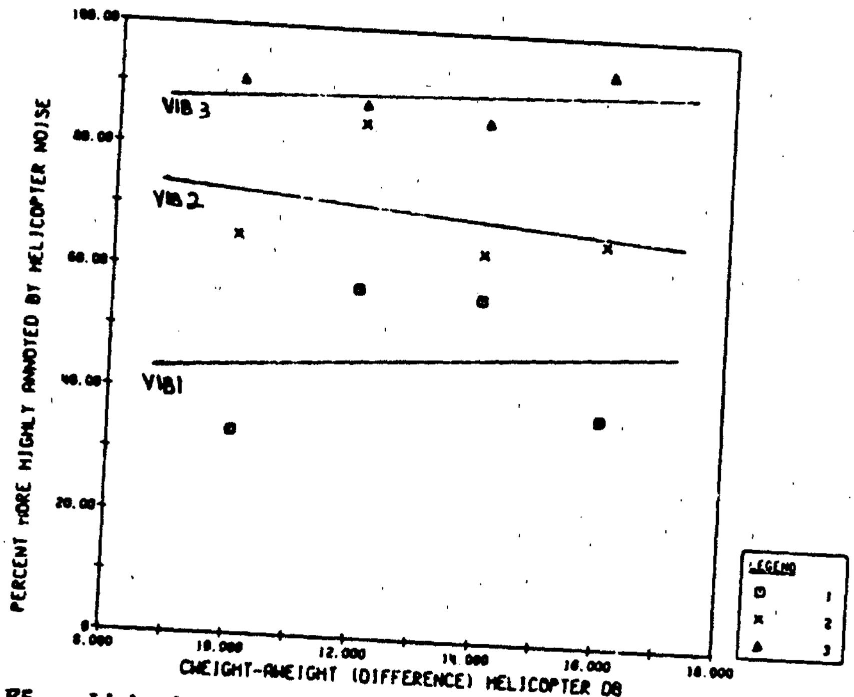


Figure F5. **Living/dining room (tent data); white noise 76 to 80 dB (A-weighted - C-weighted).**

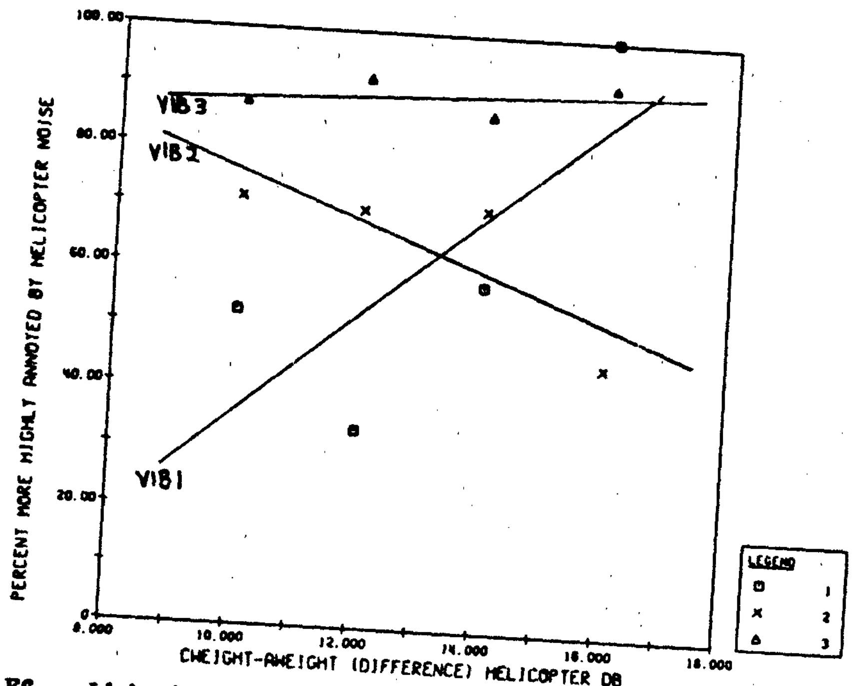


Figure F6. **Living/dining room (tent data); white noise 80 to 84 dB (A-weighted - C-weighted).**

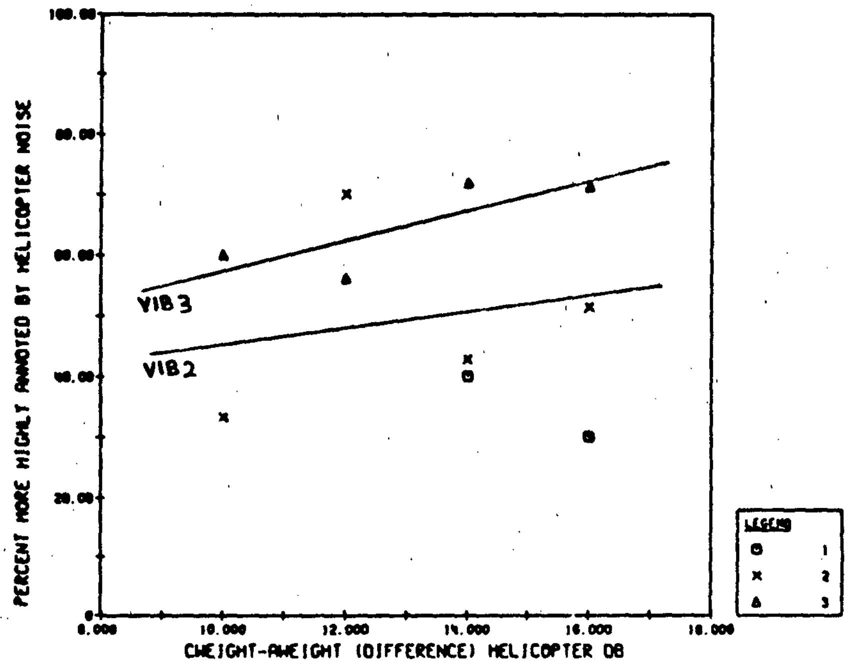


Figure F7. **Living/dining room (tent data); white noise 84 to 88 dB (A-weighted - C-weighted).**

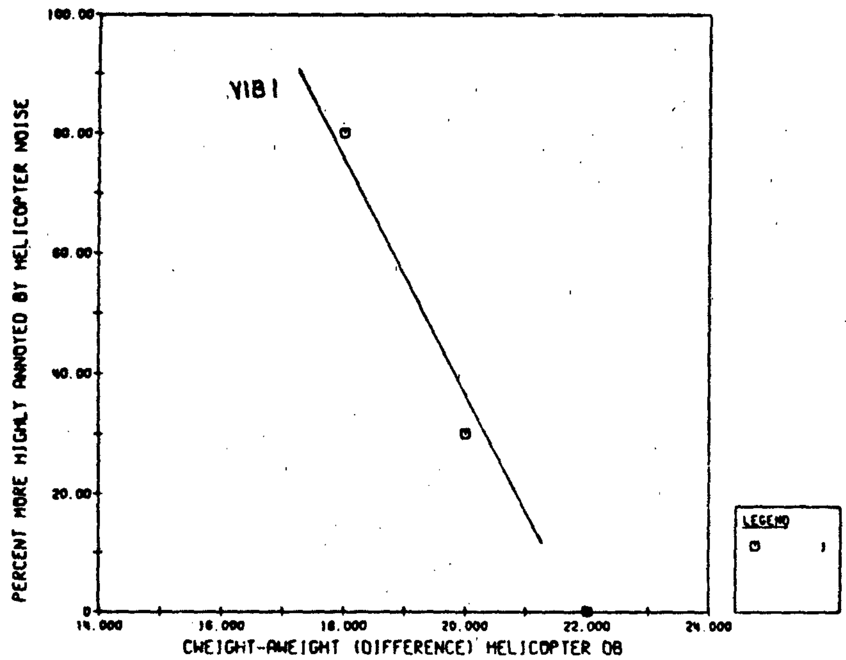


Figure F8. **Living/dining room; white noise 60 to 64 dB (A-weighted - C-weighted).**

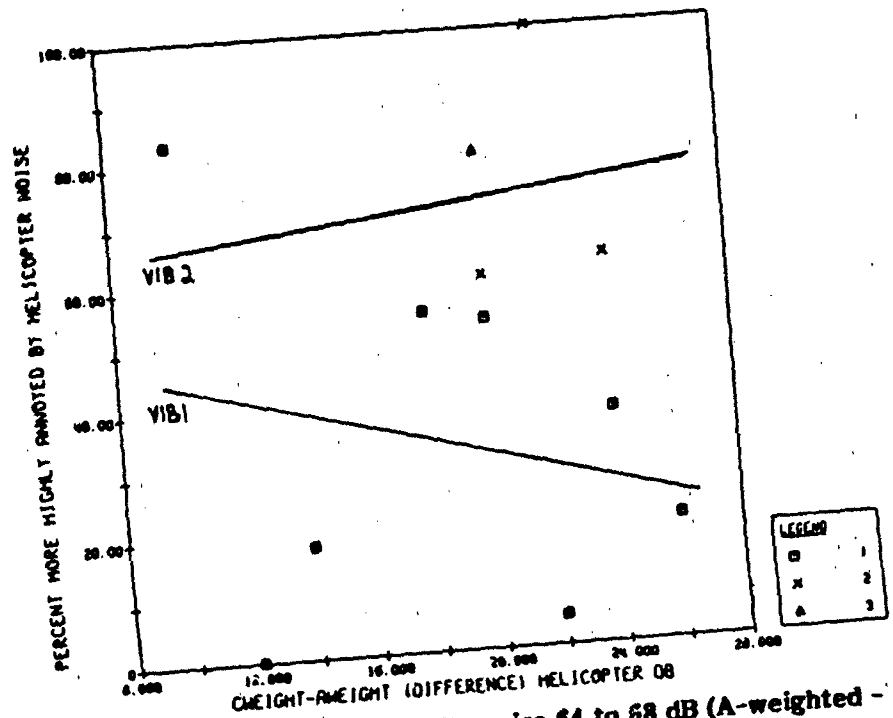


Figure F9. **Living/dining room; white noise 64 to 68 dB (A-weighted - C-weighted).**

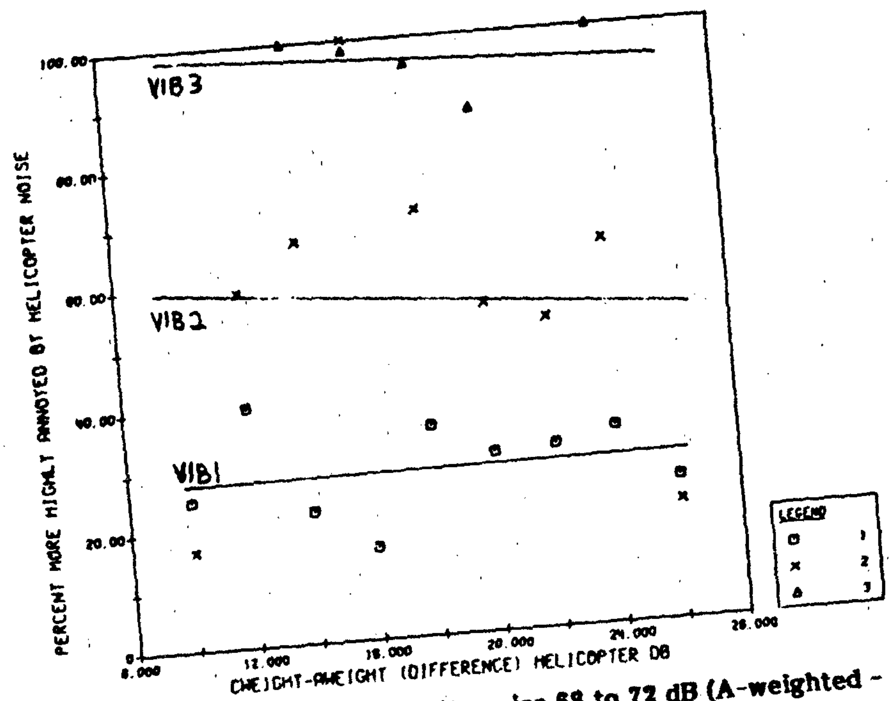


Figure F10. **Living/dining room; white noise 68 to 72 dB (A-weighted - C-weighted).**

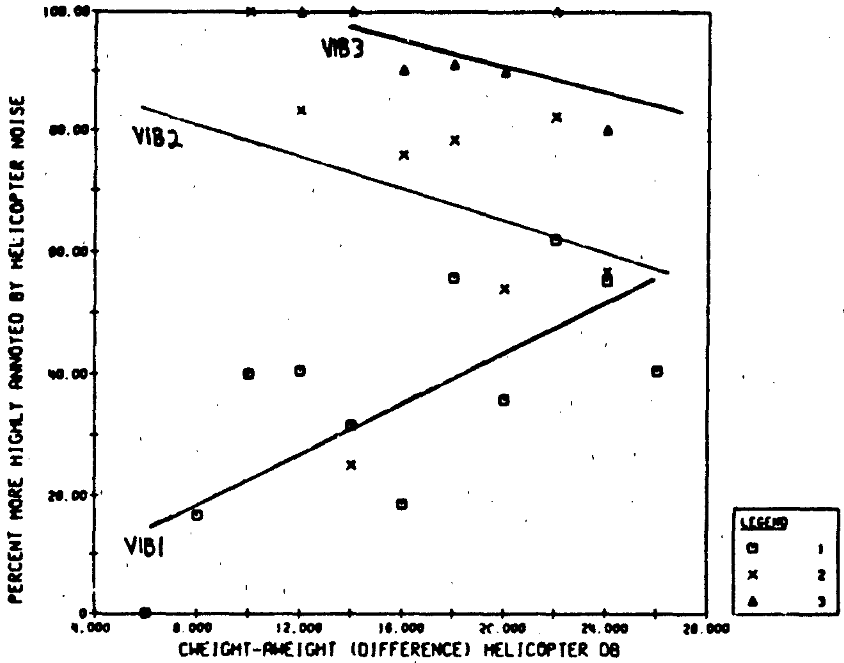


Figure F11. **Living/dining room; white noise 72 to 76 dB (A-weighted - C-weighted).**

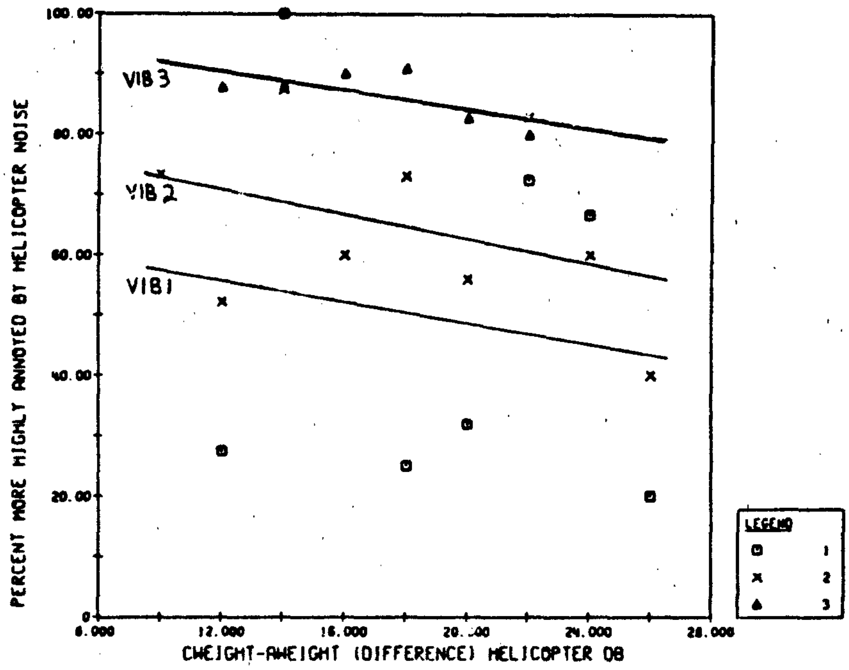


Figure F12. **Living/dining room; white noise 76 to 80 dB (A-weighted - C-weighted).**

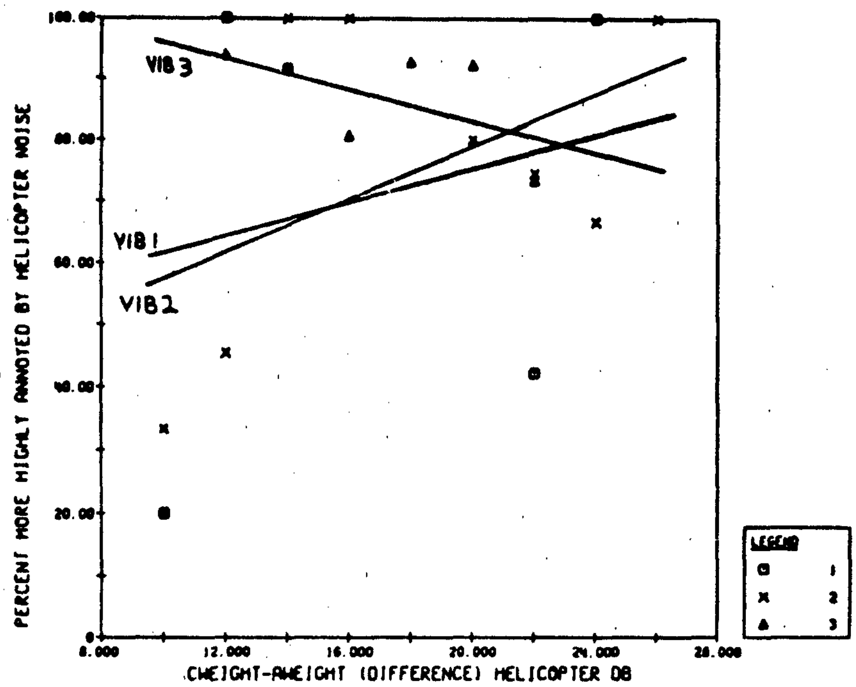


Figure F13. **Living/dining room; white noise 80 to 84 dB (A-weighted - C-weighted).**

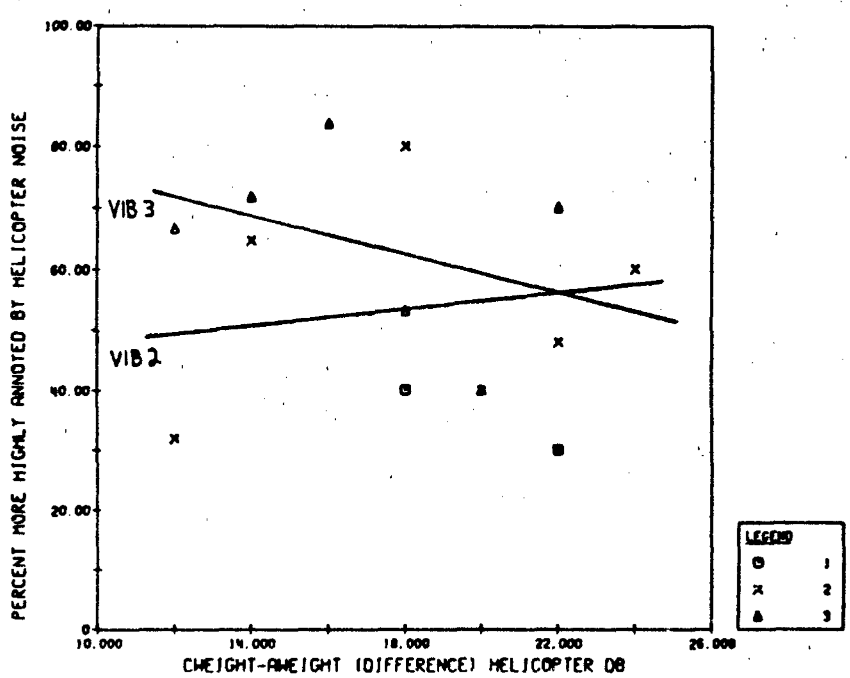


Figure F14. **Living/dining room; white noise 84 to 88 dB (A-weighted - C-weighted).**

USA-CERL DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-CCP
ATTN: DAEN-CW
ATTN: DAEN-CWE
ATTN: DAEN-CWM-R
ATTN: DAEN-CWO
ATTN: DAEN-CWP
ATTN: DAEN-EC
ATTN: DAEN-ECC
ATTN: DAEN-ECE
ATTN: DAEN-ECR
ATTN: DAEN-RD
ATTN: DAEN-RDC
ATTN: DAEN-RDM
ATTN: DAEN-RM
ATTN: DAEN-ZCE
ATTN: DAEN-ZCF
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCZ

FESA, ATTN: Library 22060
ATTN: DET III 79906

US Army Engineer Districts
ATTN: Library (41)

US Army Engineer Divisions
ATTN: Library (14)

US Army Europe
AEAEN-ODCS/Engr 09403
ISAE 09081
V Corps
ATTN: DEH (11)
VII Corps
ATTN: DEH (15)
21st Support Command
ATTN: DEH (12)
USA Berlin
ATTN: DEH (11)
USASETAF
ATTN: DEH (10)
Allied Command Europe (ACE)
ATTN: DEH (3)

8th USA, Korea (19)

ROK/US Combined Forces Command 96301
ATTN: EUSA-HHC-CFC/Engr

USA Japan (USARJ)
ATTN: AJEN-DEH 96343
ATTN: DEH-Honshu 96343
ATTN: DEH-Okinawa 96331

416th Engineer Command 60623
ATTN: Facilities Engineer

US Military Academy 10966
ATTN: Facilities Engineer
ATTN: Dept of Geography & Computer Science
ATTN: DSCPER/MAEN-A

AMMRC, ATTN DRXMR-WE 02172

USA ARRCOM 61299
ATTN: DRCIS-RI-I
ATTN: DRSAR-IS

AMC - Dir., Inst., & Servc
ATTN: DEH (23)

DLA ATTN: DLA-WI 22314

DNA ATTN: NADS 20305

FORSCOM
FORSCOM Engr, ATTN: AFEN-DEH
ATTN: DEH (23)

HSC
ATTN: HSLO-F 78234
ATTN: Facilities Engineer
Fitzsimons AMC 80240
Walter Reed AMC 20012

INSCOM - Ch, Instl. Div
ATTN: Facilities Engineer (3)

MDW, ATTN: DEH (3)

MTMC
ATTN: MTMC-SA 20315
ATTN: Facilities Engineer (3)

NARADCOM, ATTN: DRDNA-F 01760

TARCOM, Fac. Div. 48090

TRADOC
HQ, TRADOC, ATTN: ATEN-DEH
ATTN: DEH (19)

TSARCOM, ATTN: STSAS-F 63120

USACC, ATTN: Facilities Engr (2)

WESTCOM
ATTN: DEH, Ft. Shafter 96858
ATTN: APEN-IM

SHAPE 09055
ATTN: Surv. Section, CCB-OPS
Infrastructure Branch, LANDA

HQ USEUCOM 09128
ATTN: ECJ 4/7-LOE

Fort Belvoir, VA 22070 (7)
ATTN: Canadian Liaison Office
ATTN: Water Resources Support Ctr
ATTN: Engr Studies Center
ATTN: Engr Topographic Lab.
ATTN: ATZA-DTE-SU
ATTN: ATZA-DTE-EM
ATTN: R&D Command

CRREL, ATTN: Library 03755

WES, ATTN: Library 39180

HQ, XVIII Airborne Corps
and Fort Bragg
ATTN: AFZA-FE-EE 28307

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

Chanute AFB, IL 61868
3345 CES/DE, Stop 27

Norton AFB, CA 92409
ATTN: AFRCE-MX/DEE

NAVFAC
ATTN: Engineering Command (7)
ATTN: Division Offices (6)
ATTN: Naval Public Works Center (9)
ATTN: Naval School, Morell Library
ATTN: Naval Civil Engr Lab. (3)

NCEL ATTN: Library, Code L08A 93041

Defense Technical Info. Center 22314
ATTN: DDA (12)

Engr Societies Library, NY 10017

Natl Guard Bureau Instl. Div 20310

US Govt Printing Office 22304
Receiving Sect/Depository Copies (2)

US Army Env. Hygiene Agency
ATTN: HSHB-E 21010

National Bureau of Standards 20760

331
03/22/85

ENA Team Distribution

Chief of Engineers
ATTN: DAEN-ECC-E
ATTN: DAEN-ECE-B
ATTN: DAEN-ECE-I (2)
ATTN: DAEN-ZCF-B
ATTN: DAEN-ECZ-A
ATTN: DAEN-ZCE-D (2)

US Army Engineer District
New York 10007
ATTN: Chief, Design Br
Philadelphia 19106
ATTN: Chief, NAPEN-E
Baltimore 21203
ATTN: Chief, Engr Div
Norfolk 23510
ATTN: Chief, NAOEN-D
Huntington 25721
ATTN: Chief, ORHED
Wilmington 28401
ATTN: Chief, SAWEN-D
Savannah 31402
ATTN: Chief, SASAS-L
Mobile 36628
ATTN: Chief, SAMEN-D
Louisville 40201
ATTN: Chief, Engr Div
St. Paul 55101
ATTN: Chief, ED-D
Chicago 60604
ATTN: Chief, NCCPE-PES
Rock Island 61201
ATTN: Chief, Engr Div
St. Louis 63101
ATTN: Chief, ED-D
Omaha 68102
ATTN: Chief, Engr Div

New Orleans 70160
ATTN: Chief, LMNED-DG
Little Rock 72203
ATTN: Chief, Engr Div
Tulsa 74102
ATTN: Chief, Engr Div
Ft. Worth 76102 (3)
ATTN: Chief, SWFED-D
San Francisco 94105
ATTN: Chief, Engr Div
Sacramento 95814
ATTN: Chief, SPKED-D
Far East 96301
ATTN: Chief, Engr Div
Seattle 98124
ATTN: Chief, EN-DB-ST
Walla Walla 99362
ATTN: Chief, Engr Div
Alaska 99501
ATTN: Chief, NPASA-R

US Army Engineer Division
New England 02154
ATTN: Chief, NEDED-T
North Atlantic 10007
ATTN: Chief, NADEN-T
Middle East (Rear) 22601
ATTN: Chief, MEDED-T
South Atlantic 30303
ATTN: Chief, SADEN-TS
Huntsville 35807
ATTN: Chief, HNDED-CS
ATTN: Chief, HNDED-SR
Ohio River 45201
ATTN: Chief, Engr Div
Missouri River 68101
ATTN: Chief, MRDED-T
Southwestern 75202
ATTN: Chief, SWDED-T
South Pacific 94111
ATTN: Chief, SPDED-TG
Pacific Ocean 96858
ATTN: Chief, Engr Div
North Pacific 97208

6th US Army 94129
ATTN: AFKC-EN

7th Army Combined Arms Trng. Cntr. 09407
ATTN: AETTM-HRD-EHD

Armament & Dev. Command 21005
ATTN: DRDAR-BLT

US Army Tank Command
ATTN: DRSTA-SP 48090

USA ARRADCOM 07801
ATTN: DRDAR-LCA-OK

DARCOM 22333
ATTN: DRCPA-E
ATTN: DRCIS-A

TRADOC
Ft. Monroe, VA 23651

Ft. Clayton, Canal Zone 34004
ATTN: DFAE

Ft. Detrick, MD 21701

Ft. Leavenworth, KS 66027
ATTN: ATZLCA-SA

Ft. McPherson, GA 30330 (2)

Ft. Monroe, VA 23651 (6)

Ft. Rucker, AL 36360 (2)

Aberdeen Proving Ground, MD 21005
ATTN: DRDAR-BLL
ATTN: STEAP-MT-E

Human Engineering Lab. 21005 (2)

USA-WES 39181

Army Environmental Hygiene Agency 21005

Naval Air Station 92135
ATTN: Code 661

NAVFAC 22332 (2)

Naval Air Systems Command 20360

US Naval Oceanographic Office 39522

Naval Surface Weapons Center 22485
ATTN: N-43

Naval Undersea Center, Code 401 92152 (2)

Bolling AFB, DC 20332
AF/LEEEU

Patrick AFB, FL 32925
ATTN: XRQ

Tyndall AFB, FL 32403
AFESC/TST

Wright-Patterson AFB, OH 45433 (3)

Building Research Advisory Board 20418

Transportation Research Board 20418

Dept of Housing and Urban Development 20410

Dept of Transportation Library 20590

Illinois EPA 62706 (2)

Federal Aviation Administration 20591

Federal Highway Administration 22201
Region 15

NASA 23365 (2)

National Bureau of Standards 20234

Office of Noise Abatement 20590
ATTN: Office of Secretary

USA Logistics Management Center 23801

Airports and Construction Services Dir
Ottawa, Ontario, Canada K1A 0N8

Division of Building Research
Ottawa, Ontario, Canada K1A 0R6

National Defense HQDA
Ottawa, Ontario, Canada K1A 0K2

Michigan Army National Guard
ATTN: Co. B, 38th AVN
10602 Eaton Hwy
Grand Ledge, MI 48837

★ U.S. GOVERNMENT PRINTING OFFICE: 1985—641-418/640